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Dental attrition for a contemporary Western Montana population

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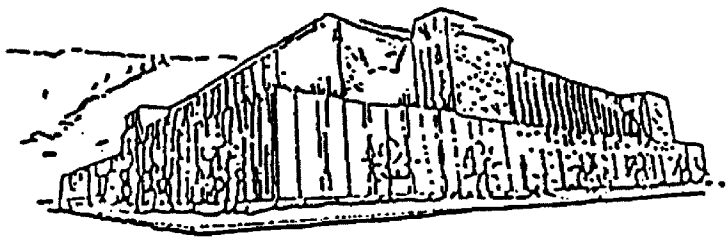

DENTAL ATTRITION FOR A CONTEMPORARY WESTERN MONTANA POPULATION

By

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Dental Attrition of a Contemporary Western Montana Population

Chairperson: Dr. Randall Skelton RS.

This thesis is concerned with forensic anthropology, a subfield of physical anthropology. forensic anthropology is concerned with obtaining information from an individual's skeletal remains, primarily to aid law enforcement investigations. Skeletal and dental remains are analyzed to estimate age, sex, race, pathology, size, demography and diet. Estimation of age from attrition of the teeth is considered a reliable method, but previous studies were based on pre-modern populations. The purpose of this thesis is to develop a reliable method for dental attrition aging that is more appropriate for forensic cases involving contemporary dental remains.

Impressions were taken and casts made of upper and lower dental arches from a contemporary Western Montana population. Individuals ranged from eighteen to seventy-five years in age. Each individual tooth was scored for the amount of attrition (wear) on the crown and placed into one of five attrition categories. Teeth and their associated attrition scores were grouped under either incisor, canine, premolar, or molar. The average age, and age range were determined for the five attrition categories of each tooth group. Charts produced from this study can be used to estimate age based on dental attrition for a contemporary Western Montana population.

Acknowledgements

I wish to thank Donna Kaparich and Karrie Lubke for their assistance with the local dentists. Gary Kerr for the much needed crown input and most of all Dr. Randy Skelton for clearing the Air.

Contents

Chapter 1

Introduction

The analysis of human skeletal remains can reveal information from which age, sex, race, diet, size and pathology may be inferred (Anderson, 1962; Bass, 1987; and Shipman, 1984). Forensic anthropologists specialize in the identification of these characteristics from human remains (Haviland, 1991). The estimation of age at death provides evidence that can be used for the study of the human fossil record, and the comparison of these fossils with their present living descendants. Estimation of age at death is also used in forensic cases. Forensic anthropology is typically considered a part of physical anthropology which is a branch of anthropology concentrating on humans as biological organisms (Haviland, 1991).

Age at death is an important datum in establishing the identity of a deceased person. As a human ages there are degenerative changes in the skeleton which are indicators of age at time of death (Shipman, 1985). Teeth are the hardest tissue of the skeleton and will likely survive longer and in better condition after death than other parts of the skeleton

(Murphy, 1959). In particular, the amount of attrition of the teeth can be a solid indicator of the age of skeletal remains. The term attrition refers to the wearing away of the teeth in the course of functional and parafunctional mandibular movement (Glickman, 1972). The degree of attrition increases with age (Dahl, 1993).

Brothwell, 1963 and Lovejoy, 1985, pioneered the method of aging by dental attrition, creating charts and scales, used in present day forensic cases. Their approach was to estimate age by one or more of the following: 1) growth of the long bones 2) cranial suture closure 3) epiphysis closure 4) pubic symphysis 5) auricular surface, and correlate the age estimation with the degree of dental attrition present (Brothwell, 1963; Lovejoy, 1985; and Gustafson, 1950). They compiled this information into charts and tables showing the correspondence between attrition stages and age for the specific population studied.

The main problem with dental attrition aging is that each population has a unique rate of attrition (Bass, 1987). Rate of attrition can be related to the abrasiveness of the diet (Shipman, 1985; Smith, 1984; Scott, 1979; Richards, 1991; and Molnar, 1971). Abrasive materials in food have more impact on tooth wear than the hardness of the food (Dahl, 1993). Dental attrition is accelerated in populations with an abrasive diet. For example, some American Indians used grinding stones which

added grit to the diet and accelerated the rate of attrition (Eccles, 1974; Nelson, 1937; and Wissler, 1931). The ethnographically known Australian Aborigines use similar food processing techniques and showed accelerated attrition compared to contemporary western populations (Molnar, 1983; Richards, 1991).

Other factors that contribute to a contemporary population's general attrition are: 1) excessive or improper brushing (Beyron, 1954; and Johansson, 1994); 2) consuming large quantities of acidic based beverages such as soft drinks (Glickman, 1972); 3) Alcoholism, which contributes to wear through the excessive alcohol in the mouth cavity, excessive regurgitation and lack of proper dental care (Smith, 1989); 4) eating disorders, such as anorexia and bulimia, that result in continuous regurgitation exposing teeth to above normal amounts of acid (Dahl, 1993; and Eccles, 1974); 5) the environment, such as living in a desert where sand particles enter the mouth through food and water intake or from respiratory activity and act as an abrasive agent (Molnar, 1986); 6) occupational activity, such as mining, iron working and quarrying which adds abrasive material, such as sand and dirt, to the mouth cavity (Enbom, 1986; and Dahl, 1993) In pre-modern populations, factors such as alcoholism, environment and occupational activity could have also affected the rate of attrition (Davies, 1955).

Currently, studies based on pre-modern populations are used for estimating the age of people from contemporary populations. However with so many factors affecting attrition and the change in dental hygiene and diet over time, this approach is unlikely to yield truly accurate estimates of age for contemporary populations. It is the objective of this research to produce an attrition chart that can be applied to a contemporary population.

In previous studies, data were collected using the teeth of deceased individuals (Brothwell, 1963; and Lovejoy, 1985). However with a contemporary population, some method was needed for collecting dental attrition data without relieving individuals of their teeth. This study relies on the method of taking dental impressions and creating casts that replicate an individuals dentition. The study by Johansson (1993) demonstrates that a set of maxillary and mandibular casts obtained for each individual using standard alginate impressions and poured in dental stone, could represent attrition accurately. Using this method, the research presented herein will provide data for forensic anthropologists, medical examiners and law enforcement personnel to estimate age from dental attrition in contemporary skeletal remains.

The goal of this study is to develop a set of dental attrition aging standards that can be used to estimate age for

the contemporary population of Western Montana. My central hypothesis is that a significant amount of variability in dental attrition is due to age. If this hypothesis is true, then dental attrition aging would be a useful technique for estimating the age of people from Western Montana.

Chapter 2

Methodology

The sample upon which this study is based consisted of 54 dental impressions taken by Western Montana dentists and the author. Impressions were taken with alginate and impression plates. Casts of the upper and lower dentition of 34 individuals of known age and sex were obtained from Western Montana dentists. This sample did not, however, include any individuals younger than 30 years. In order to fill the lower age range, twenty volunteers between the age of eighteen and thirty were recruited from classes at the University of Montana - Missoula. Eighteen was considered the lowest age of interest because this is the average age for third molar eruption (Dahlberg, 1963; Gustafson, 1950; and Bass, 1987). These two samples combined yielded a total of 54 casts for the research project.

Impressions for the twenty volunteers from University of Montana - Missoula were taken by the author using impression plates, alginate and dental stone. Impression plates were soaked in ethyl alcohol before each use to insure sterility.

Alginate is a powder that forms a gelatinous substance when mixed with water, and is spread onto the impression plate. Plates are then applied to the upper and lower dental arches of the subject. When removed, the impressions are filled with liquid dental stone and allowed to harden. The hardened stone is then separated from the alginate, producing a cast of the subjects dentition.

An initial evaluation was done to exclude teeth with more than 40% coverage by fillings, capping of the tooth or inferior casting. Any one set of upper and lower casts with more than 60% of the teeth excluded were removed from the study population. The final set of casts for the study numbered thirty. Of these, the third molars were excluded from evaluation due to lack of representation. Extraction of third molars is common in contemporary western populations (Banks, 1934; and Goldstein, 1932). This left a total of 461 teeth to be evaluated for this study.

A standard numbering system for the teeth was used (appendix 1). In this system tooth #1 is the upper right third molar, and numbers progress counter clockwise on the upper arch to the upper left third molar, tooth #16. Tooth #17 is the lower left third molar with numbers progressing clockwise to tooth #32, the lower right third molar.

Evaluations of the degree of attrition were performed by the author using a stereo microscope equipped with a 2 mm grid

lens to determine size of dentine exposure. Grading of wear was done on a tooth by tooth basis and compared to an ordinal scale with 5 progressive degrees of attrition. The attrition scoring scale is shown in table 1. Graphical representations are shown in appendix 2.

Table 1. Dental attrition scoring system

0 = No dentine exposed

1 = Pinprick sized dentine exposed

2 = Dentine exposure larger than a pinprick, but not greater than 1mm in two dimensions

3 = Dentine exposure between 1 mm and 2 mm in at least two dimensions

4 = Dentine exposure larger than 2 mm in two dimensions, or exposure of the pulp cavity

For each tooth used in the study (teeth #2-15 and 18-31), the ages of individuals who were scored as falling into each of the 5 attrition categories were tabulated. An example, for tooth #7, is shown in table 2.

Table 2. Ordinal attrition chart with all ages for tooth #7

Tooth #7

Attrition Stage

	0	1	2	3	4
A	19	20	24	39	75
g	20	29	36	55	
e	20	29	35	67	
	31		49		
	26				
	18				

Statistical Analysis

Once the data were categorized for all teeth, statistics were applied. Statistical analysis was conducted using Quattro Pro version 4.0 software on a personal computer. All attrition scores and corresponding ages for a given tooth were placed into a spreadsheet and sorted by age, from youngest to oldest. Taking age as the independent variable and wear as the dependent variable, a linear regression analysis was performed, which yielded the following statistics: 1) the number of observations; 2) the slope and intercept of the regression line (labelled X coefficient and constant,

respectively, in the Quattro pro output); 3) the squared correlation coefficient (labelled R2 in the Quattro pro output); and 4) standard error values for the slope of the regression line and for estimates made using the regression equation (labelled standard error of X coefficient and standard error of Y estimate, respectively). The most interesting information here is the squared correlation coefficient which represents the percentage of variability in dental attrition due to age.

For each tooth of each individual the expected attrition score was obtained using the regression formula. This estimate was used for comparison with the actual wear observed so as to remove any outlier which would bias the results one way or the other. Outliers were identified as being more than two standard errors from the expected attrition score estimate. After removing outliers a new regression analysis was run. Teeth evaluated for this study were placed into the category molar, premolar, canine or incisor. This was done because of the limited number of teeth in the study, and the similarity in age ranges for attrition stages of each one of the four tooth types. The average age was obtained for each wear stage by taking the mean of all ages in that stage and rounding to one decimal place. Standard deviation was also obtained for each wear stage.

For each tooth type (molars, premolars, canines, and

incisors a table was constructed showing, for each attrition stage, the number of observations, average age of people exhibiting that stage of wear, standard deviation of age for that stage of wear, and a calculated age range for that stage of wear. Age ranges were calculated as the average age plus/minus one standard deviation.

A graph of age versus wear was generated for each numbered tooth used in the study, and for the pooled molar, premolar, canine, and incisor data.

Chapter 3

Results

It was found that age explained 73.25% of the variability in dental attrition for molars, 64.86% for premolars, 65.05% for canines, and 63.32% for incisors. All spreadsheets and graphs for numbered teeth are shown in appendix III. Tables 3 through 6 show the number of observations, mean age, standard deviation, and age range for each group of molars, premolars, canines and incisors. Figures 1 through 4 show the relationship between age and attrition score for the molars, premolars, canines, and incisors.

Table 3. Molar attrition

Stage	Number of observations	Average age	Standard deviation	Age range
0	58	22	4.3	18 - 26
1	18	32	6.1	26 - 38
2	7	34	3.5	30 - 37
3	13	58	13.0	52 - 65
4	Not represented in the population			

Figure 1

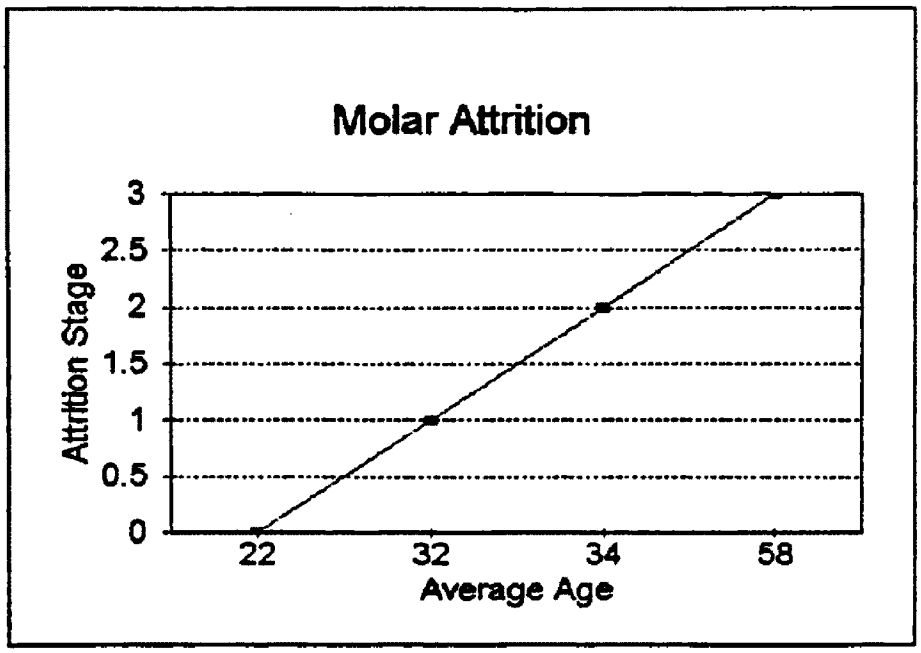


Table #4. Premolar Attrition

Stage	Number of observations	Average age	Standard deviation	Age range
0	72	21	4.2	18 - 25
1	37	28	5.8	22 - 34
2	14	39	4.8	34 - 44
3	13	61	8.7	52 - 70
4	Not represented			

Figure 2

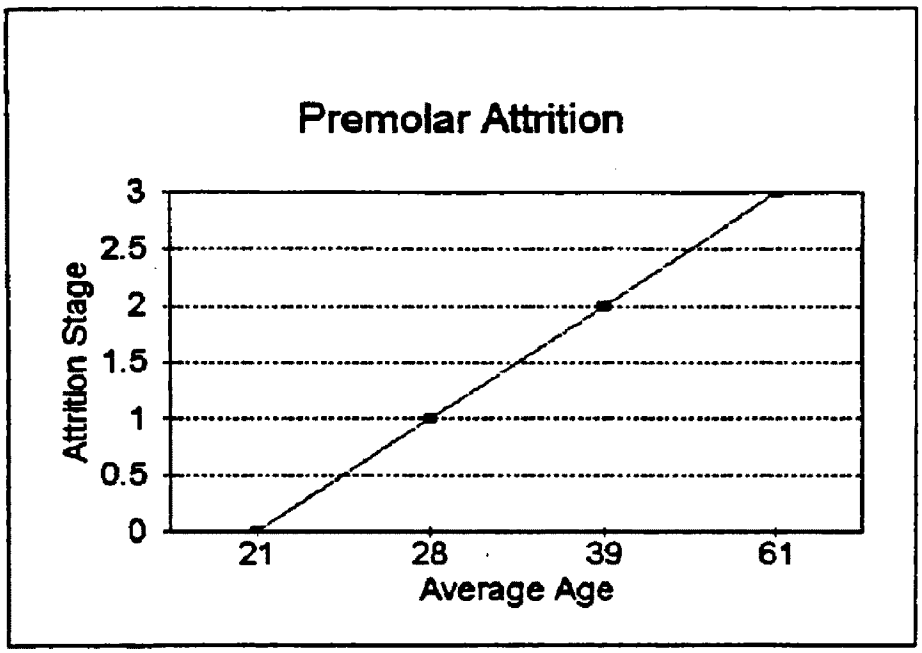


Table #5 Canine attrition

Stage	Number of observations	Average age	Standard deviation	Age range
0	27	20	2.2	18 - 22
1	21	27	6.0	21 - 33
2	17	37	10.3	26 - 47
3	20	55	17.2	38 - 72
4	Not represented			

Figure 3

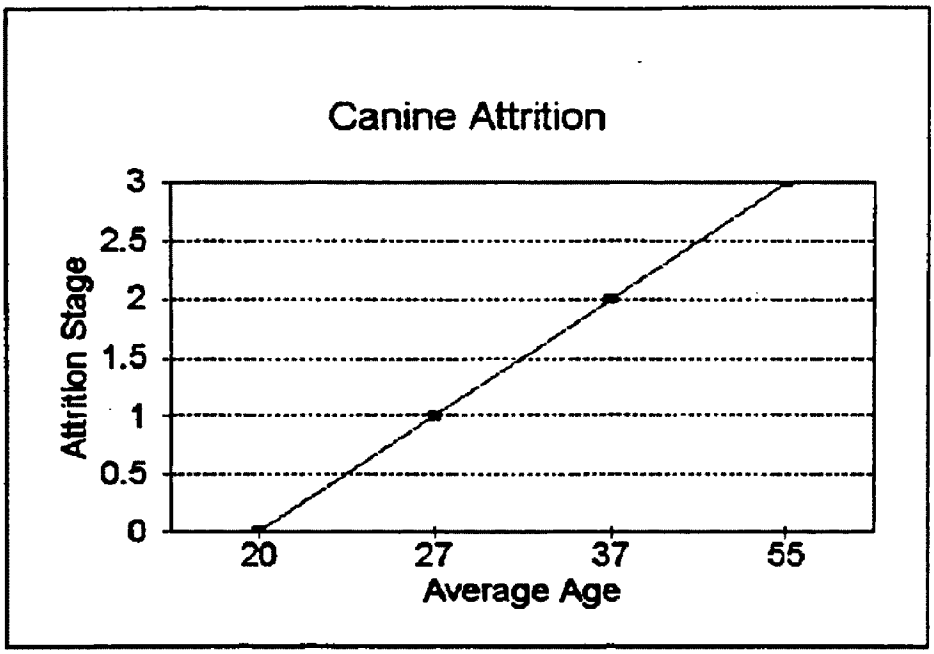
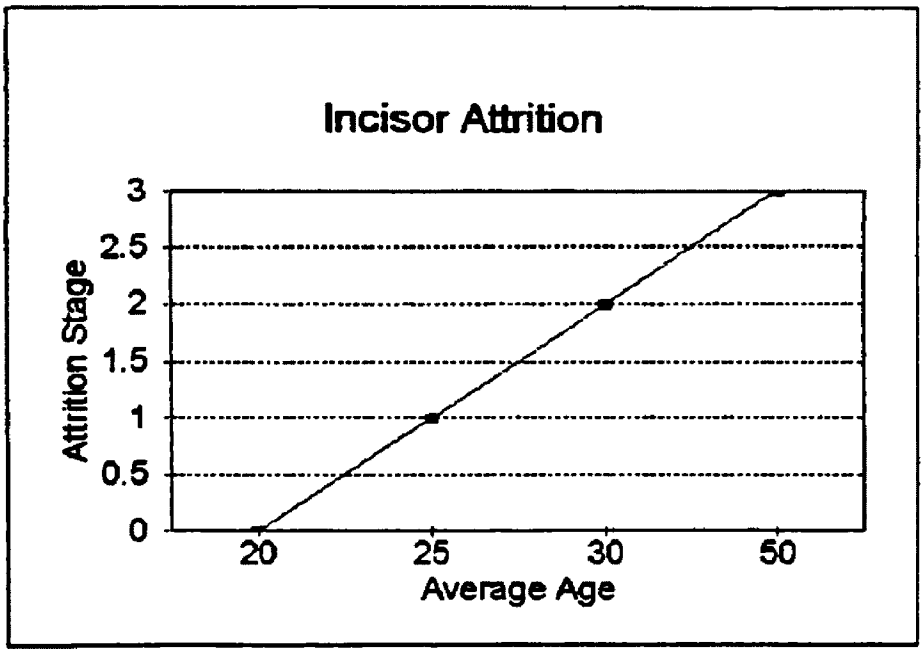


Table #6 Incisor attrition

Stage	Number of observations	Average age	Standard deviation	Age range
0	48	20	2.3	18 - 23
1	33	25	4.8	21 - 30
2	31	30	6.7	24 - 37
3	38	50	15.7	39 - 70
4	Not represented			

Figure 4



Chapter 4

Discussion

The charts shown in the results section list average ages and age ranges corresponding to the attrition stages depicted in the attrition charts in Appendix II. Together, these can be used to estimate the age of skeletal remains from dentition for a contemporary population. The accuracy will, however, be dependent on the interpreter understanding factors that affected the results and proper use of the results.

Due to mobility of travel in a contemporary western society, all of the study population can not be considered as originating from Western Montana. They were however located in the geographical area of the study at the time of study, and therefore do constitute a sample of people who might be found in Western Montana at any given time. Future research should take this factor into account.

When one thinks of a contemporary society's dental practices, brushing, flossing and trips to a dentist come to mind. The purpose of these practices is to prevent tooth decay and maintain a nice smile. Another result of these is,

however, to retard or accelerate attrition to a certain degree. The presence of dental work is also important. The study did not find even one set of casts that lacked some sort of dental work. While certain contemporary factors discussed in the introduction, such as acidic drinks like soda pop, may increase attrition, this study did not take these factors into account.

The average age for all charts for stages 0, 1 and 2 are fairly well defined and have a progression that seems logical, given the fact that attrition takes place over time. There is a larger difference in the averages for stage 2 and 3. This is due in part to the limited number of teeth scored as stage 3. Relatively few teeth were scored as stage 3 because many of them were removed from the study because they had fillings. The fact that stage 4 is not represented at all reflects the probability that persons in this study did not let their teeth progress to that stage of dentine exposure, but sought dental treatment instead. Therefore stages 0 through 2 will give more reliable estimates of age than stages 3 and 4.

The age ranges are the most important results of this study. They provide the interpretive framework that the forensic examiner needs to estimate age for skeletal remains. It is important to keep in mind that estimates of age need to be expressed as age ranges. One should not proclaim remains to be 22 years of age based on the attrition and average age, but

state that they are possibly between a certain range of ages.

The age ranges for stages 0, 1 and 2 overlap considerably in some cases, a little in others, and have clear cut boundaries in some. Stage 3 exhibits age ranges that vary in size from thirty-four years for the incisors to thirteen years for the molars. The anterior teeth, incisors and canines, exhibit the largest variation in attrition while the premolars and molars exhibited less variation. This could result from the fact that the anterior teeth erupt in the oral cavity sooner than the posterior teeth (Bass, 1987; Davies, 1955; Garn, 1959; Hunt, 1955; Kronfeld, 1935; and Seligman, 1988).

An effective use of the charts would be to examine all teeth present in a set of remains and use the combined results from the charts to give a possible age range for the skeletal remains. To accomplish this, compare the state of wear of the individual's dental remains with the dental attrition scoring system (Table 1), and the diagrams for dentine exposure in appendix II, to establish an attrition score for the individual. Then use the tooth type tables in the results section to find the age range corresponding to the attrition stage. For example assume that some skeletal remains are discovered, a mandible with a molar, two premolars, and a canine. To estimate age from dental attrition first determine the tooth types (a good reference for determination of tooth type is located in Bass, 1987). Comparison to table 1 and

appendix II shows that all exhibit no dentine exposure and are therefore stage 0. When compared to the attrition tables this gives an age range of 18 - 26 for the molar, 18 -25 for premolars and 18 - 22 for the canine. By combining age ranges, both a narrow and a wide final age range can be generated. The best summary of age based on attrition information would state that the age could be between 18 and 26, with the highest probability of being between 18 and 22.

There may be times when variability in wear from tooth to tooth causes overly wide age estimation ranges (for example 18 to 50). In this circumstance other age estimators, such as suture closure, epiphysis closure, pubic symphysis morphology or other means of age estimation should be consulted to narrow the age range.

Chapter 5

Conclusion

The purpose of this thesis was to construct a dental attrition chart for estimating age in forensic anthropological investigations of people belonging to the contemporary Western Montana population. The central hypothesis of this study, that age explains a significant amount of the variability in attrition, was supported by the results of this study. Therefore, dental attrition aging can be considered a useful technique when applied to the contemporary population of Western Montana - provided that the method detailed herein is used. The results and discussion sections provide usable charts and information for such a practice. This thesis also provides information about our contemporary culture, concerns for the forensic anthropologist and a need for further research.

It can be inferred from the data that the contemporary Western Montana population is concerned with dental hygiene and supports their local dentist. Both the solicited casts from local dentists and those taken by the author exhibited some form of dental alteration, such as fillings, caps or braces. The sample of individuals age 18 to 38 in the study

exhibited less alteration than those individuals over 40 years of age. This is indicated by the higher amount of teeth removed from the study in the over 40 age range, due to dental alteration. Those individuals from 18 to 38 exhibited a steady reduction in enamel while older individuals seem to stay constant at one stage of attrition. Although alteration is present in the 18 to 38 age range it is not as prevalent as in the 40 and over range. Concern with dental health appears to be a fact for the population in this study.

According to the data presented in this thesis, the forensic anthropologist should have concerns when using the attrition chart for stages 3 and 4 of dental attrition. Stage 3 has a wide age range and stage four is not represented, both results of a lack of data, due to the fact that teeth with extensive dental alteration were eliminated from consideration in this study. The positive result of this is that people with extensive dental alteration may be more easily identified from dental records.

While this thesis provides usable attrition data for forensic investigations, it does raise concerns. The fact that dental alteration affected the results may in part be due to obtaining casts from local dentists. If a dentist is making a cast it is usually in preparation for dental alteration. Further research should take this factor into

account and concentrate on obtaining casts from a random selection of subjects within a specific population. Since contemporary populations differ not only in diet but other factors, it is recommended that studies enlarge their data base to more than the fifty-four individuals used for this study.

References

Anderson, J.E.
1962 The Human Skeleton: A Manual of Archaeologists. Ottawa: National Museum of Canada.

Banks, H.V.
1934 Incidence of Third Molar Development. Angle Orthodontist 4:273.

Bass, William M.
1987 Human Osteology: A laboratory and Field Manual. Special Publication No. 2. Missouri Archaeological Society Columbia, Missouri.

Brothwell, D.R. (editor)
1963 Dental Anthropology. New York: MacMillan.

Beyron, H.L.
1954 Occlusal Changes in the Adult Dentition. Journal of the American Dental Association 48:674.

Dahl, B.L., Carlsson G.E. and Anders Ekfeldt
1993 Occlusal Wear of Teeth and Restorative Materials. A Review of Classification, Etiology, Mechanisms of Wear, and Some Aspects of Restorative Procedures. Acta Odontol Scand 299-311.

Dahl, B.L., Krogstad O. and K. Karlsen
1975 Alternative Treatment in Cases with Advanced Localized Attrition. Journal Oral Rehabilitation 2:209-214.

Dahl, B.L., Oilo G., Anderson A. and Oddbjorn Bruaset
1989 The Suitability of a New Index for the Evaluation of Dental Wear. Acta Odontol Scand 47:205-210.

Dahlberg, A.A
1949 The Dentition of the American Indian. The Physical Anthropology of the American Indian. New York, pg 138-76.

Dahlberg, A.A.
1963 Dental Traits as Identification Tools. Dental Progress 3:155-60.

Davies, T.G.H. and P.O. Pedersen
1955 The Degree of Attrition of the Deciduous Teeth and First Permanent Molars of Primitive and Urbanized Greenland Natives. British Dental Journal 99:35-43.

Enbom, L., Magnusson T. and G. Wall
1986 Occlusal Wear in Miners. Swedish Dental Journal 10:165.

Eccles, J.D. and W.G. Jenkins
1974 Dental Erosion and Diet. Journal of Dentistry 2:153-159.

Garn, S.M., Lewis, A.B. and D.L. Polacheck
1959 Variability of Tooth Formation. Journal of Dental Research 38:135-48.

Glickman, I.
1972 Clinical Periodontology: Prevention, Diagnosis and Treatment of Periodontal Disease in the Practice of General Dentistry. Fourth Edition. W. B. Saunders Co., Philadelphia.

Goldstein, M.S.
1932 Congential Absence and Impaction of the Third Molar in the Eskimo Mandible. American Journal of Physical Anthropology 16:381-88.

Goldstein, M.S.
1948 Dentition on the Indian Crania From Texas. American Journal of Physical Anthropology 6:63-84.

Gourdon, A.M., Buyle-Bodin Y., Woda A. and M. Faraj
1987 Development of and Abrasion Index. Journal of Prosthetic Dentistry 57:358.

Gustafson, G.
1950 Age Determination in Teeth. Journal of American Dental Association 41:45-54.

Haviland, W.A.
1991 Anthropology. Holt, Rhinehart and Winston, Inc. Fort Worth.

Helm, S. and V. Prydso
1979 Molar Attrition in Medieval Danes. Scand Journal of Dental Restoration 87:79-90.

Hellman, M.
1928 Racial Characters in Human Dentition. Proceedings of the American Philosophical Society 67:157-74.

Hellman, M.
1940 Wisdom Teeth in the Lower Jaw. Archives of Clinical and Oral Pathologies 4:171-86.

Hunt, E.E., and I Gleisor
1955 The Estimation of Age and Sex of Preadolescent Children From Bone and Teeth. American Journal of Physical Anthropology 13:479-87.

Iscan, M.Y.
1989 Age Markers in the Human Skeleton. C.C. Thomas.

Iscan, M.Y.
1989 The Emergence of Dental Anthropology. American Journal of Physical Anthropology 78:1-2.

Johansson, Anders
1994 Identification and Management of Tooth Wear. International Journal of Prosthodontics 7:506-516.

Johansson, A., Haraldson T., Omar R. Kiliaridus S. and Carlson G.
1993 A System for Assessing the Severity and Progression of Occlusal Tooth Wear. Journal of Oral Rehabilitation 20:125-131.

Kronfeld, R.
1935 Development and Calcification of Human Deciduous and Permanent Dentition. The Bur 35:18.

Lewis, A. B., and S. M. Garn
1960 The Relationship Between Tooth Formation and Other Maturational Factors. Angle Orthodontist 30:70.

Lovejoy, C.O., Meindl, R.S., Mensforth R.P., and T.J. Barton
1985 Multifactorial Determination of Skeletal Age at Death: A Method and Blind Tests of its Accuracy. American Journal of Physical Anthropology 68:1-14.

Lovejoy, C.O.
1985 Dental Wear in The Libben Population: Its Functional Pattern and Role in the Determination of the Adult Skeletal Age at Death. American Journal of Physical Anthropology 68:47-56.

Molnar, S.
1971 Human Tooth Wear, Tooth Function and Variability. American Journal of Physical Anthropology 34:175-90.

Molnar, S., McKee J.K., Molnar I.M. and T.R. Przybeck
1983 Tooth Wear Rates Among Contemporary Australian Aborigines. Journal of Dental Research 62:562.

Molnar, S., Richards L., Mckee J., and I. Molnar
1989 Tooth Wear in Australian Aboriginal Populations from the River Murry Valley. American Journal of Physical Anthropology 79:185-97.

Murphy, T.
1959 Gradients of Dentine Exposure in Human Molar Teeth Attrition. American Journal of Physical Anthropology 17:179-86.

Nelson, C.T.
1937 The Teeth of Indians of the Pecos Pueblo. American Journal of Physical Anthropology 23:261-93.

Nowell, G.W.
1978 An Evaluation of the Miles Method of Aging using the Tepe Hissar Dental Sample. American Journal of Physical Anthropology 49:271-76.

Olio, G., Dahl B., Hayle G. and A.L. Gad
1987 An Index for Evaluating Wear of Teeth. Acta Odontologica Scandinavica 45:361.

Pollman, L. Berger F. and B. Pollmann
1987 Age and Dental Abrasion. Gerodontics 3:94-96.

Reinhardt, G.A.
1983 Relationships Between Attrition and Lingual Tilting in Human Teeth. American Journal of Physical Anthropology 61:227-237.

Richards, L.C. and S.L.J. Miller
1991 Relationships Between Age and Dental Attrition in Australian Aboriginals. American Journal of Physical Anthropology 84:159-64.

Scott, E.C.
1979 Dental Wear Scoring Techniques. American Journal of Physical Anthropology 51:213-18.

Seligman, D.A., Pullinger A.G. and W.K. Solberg
1988 The prevalence of Dental Attrition and its Association with Factors of Age, Gender Occlusion and TMJ Symptomatology. Journal of Dental Research 10:1323-1333.

Shipman, P.A., A. Walker and D. Bichell
1985 The Human Skeleton. Harvard University Press, Cambridge.

Smith, B.G.N. and J.K. Knight
1984 An Index for Measuring the Wear of Teeth. British Dental Journal 156:435.

Smith, B.G.N. and R.D. Robb
1989 Dental Erosion in Patients with Chronic Alcoholism. Journal of Dentistry 17:219-221.

Smith, B.H.
1984 Patterns of Molar Wear in Hunter-Gatherers and Agriculturalists. American Journal of Physical Anthropology 63:39-56.

Smith, W.
1894 The Teeth of the Sioux Indians. Journal of the Anthropological Institute of Great Britain and Ireland 24:109-16.

Teaford, M.F. and C.A. Tylenda
1991 A New Approach to Tooth Wear. Journal of Dental Research 70:204.

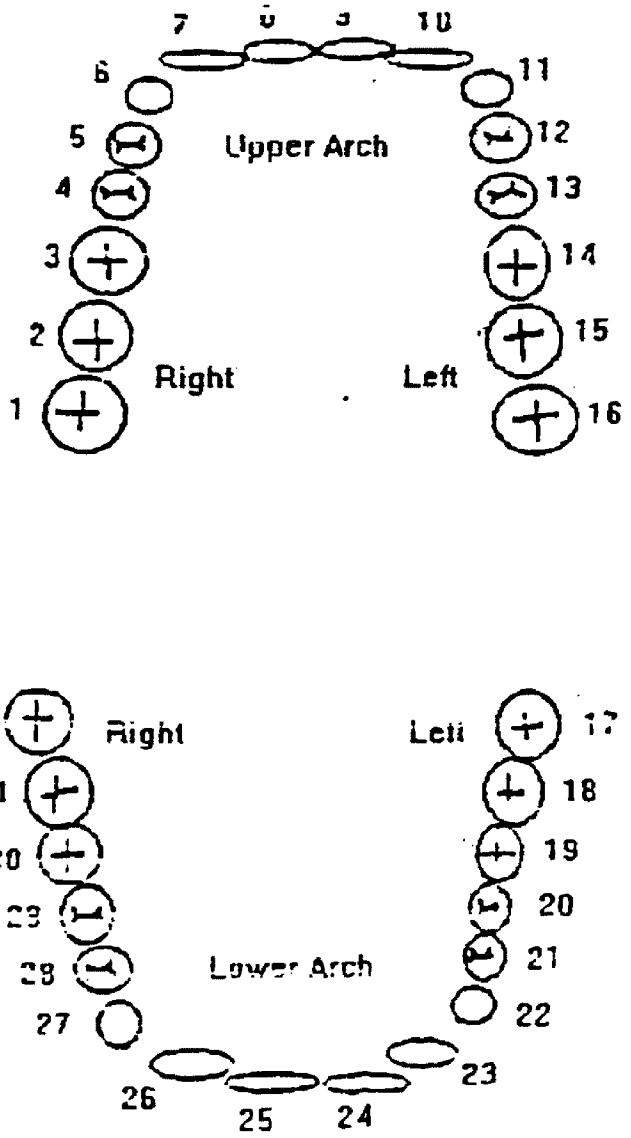
Turner, C.G. and L.M.C. Machado
1983 New Dental Wear Pattern of Brazilian Archaic Skeletal Population. American Journal of Physical Anthropology 61:125-130.

Tushar, F.J. and J.E. Bowman
1995 Age Determination From Dental Microstructure in Juveniles. American Journal of Physical Anthropology 97:135.

Walker, P.L.
1978 A Quantitative Analysis of Dental Attrition Rates in the Santa Barbara Channel Area. American Journal of Physical Anthropology 48:101-06.

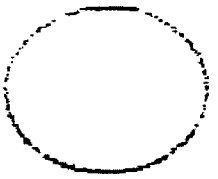
Wissler, C.
1931 Observations on the Face and Teeth of the North American Indians. Anthropological Papers of the American Museum of Natural History 33:1-33.

Appendix I

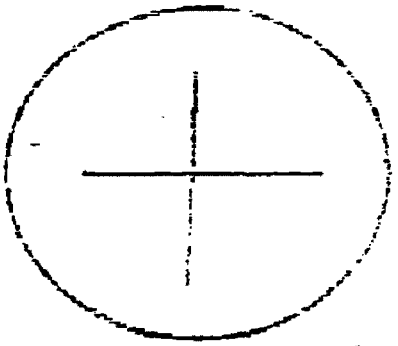


Appendix II

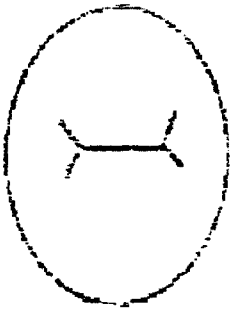
Incisor Attrition Stage #0



Canine Attrition Stage #0

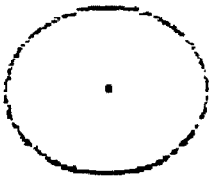


Molar Attrition Stage #0

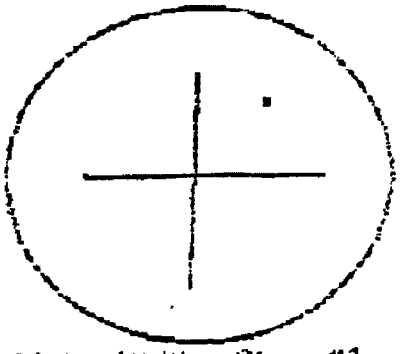


Premolar Attrition Stage #0

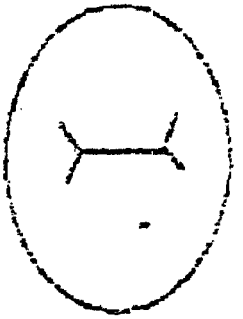
Incisor Attrition Stage #1



Canine Attrition Stage # 1

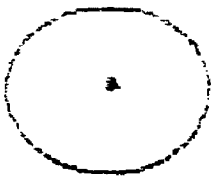


Molar Attrition Stage #1

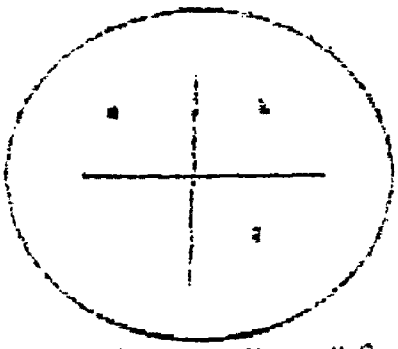


Premolar Attrition Stage #1

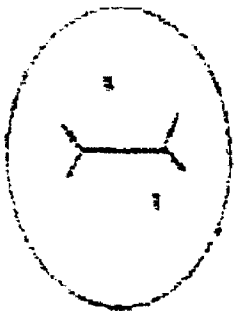
Incisor Attrition Stage # 2



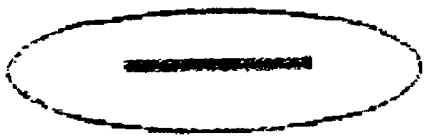
Canine Attrition Stage # 2



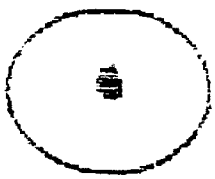
Molar Attrition Stage # 2



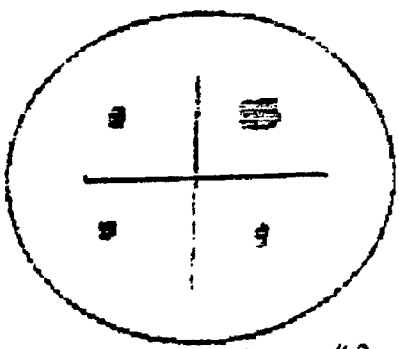
Premolar Attrition Stage # 2



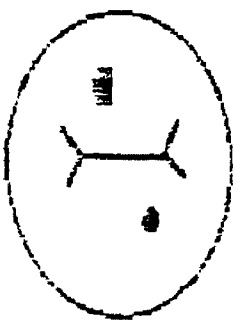
Incisor Attrition Stage # 3



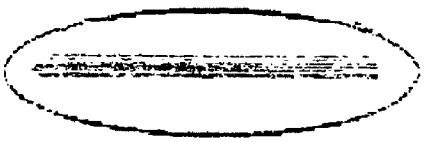
Canine Attrition Stage # 3



Molar Attrition Stage # 3

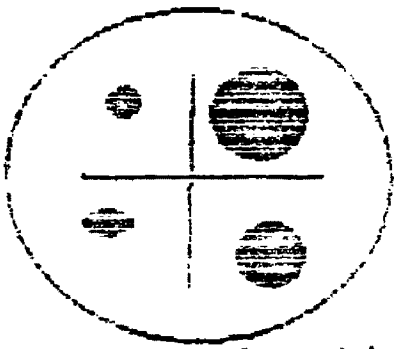


Premolar Attrition Stage # 3

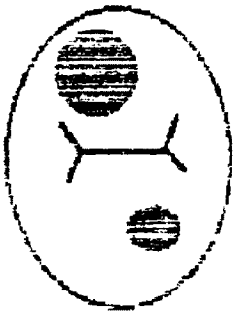


Incisor Attrition Stage # 4

Canine Attrition Stage # 4



Molar Attrition Stage # 4



Premolar Attrition Stage # 4

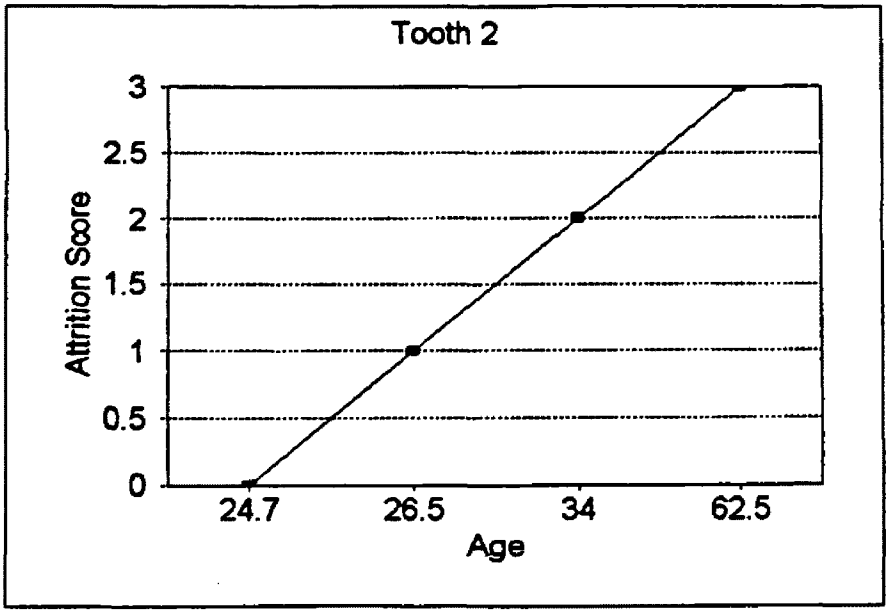
Appendix III

Tooth 2

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	3	24.7	5.7	19-30
1	2	26.5	3.5	23-30
2	2	34	5	29-39
3	2	62.5	12.5	50-75
4	0	0	0	0

Regression Output:

Constant	-0.68757
Std Err of Y Est	0.77407
R Squared	0.65048
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	0.05684
Std Err of Coef.	0.01575



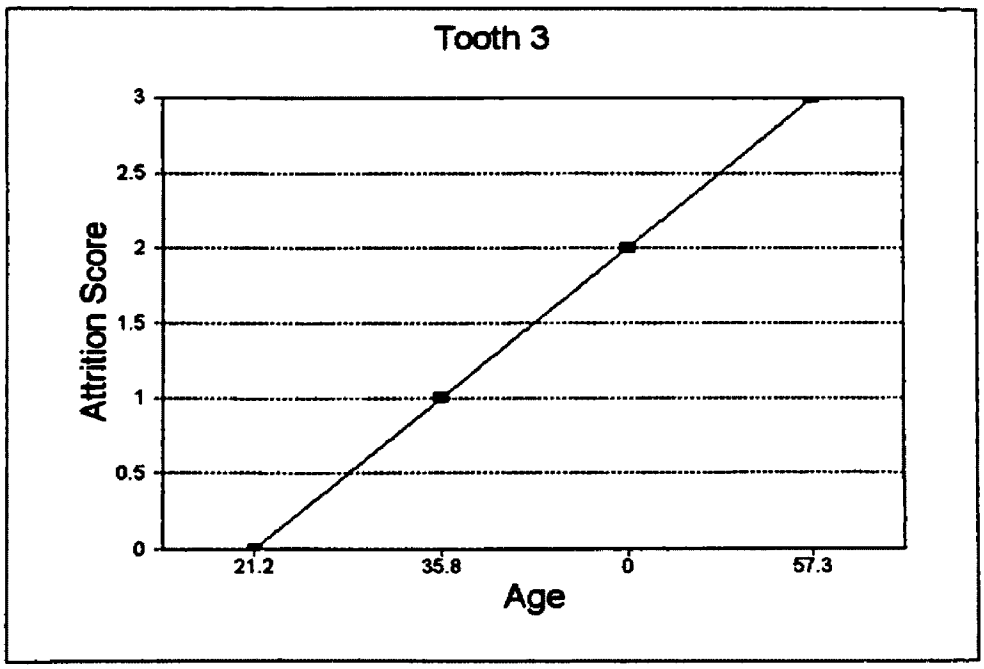
Tooth 3

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	21.2	7.7	18-29
1	4	35.8	13.6	22-49
2	0	0	0	0
3	3	57.3	15.4	42-72
4	0	0	0	0

Regression Output:

Constant	-1.06478
Std Err of Y Est	0.63939
R Squared	0.71995
No. of Observations	16
Degrees of Freedom	14

X Coefficient(s)	0.05936
Std Err of Coef.	0.00989



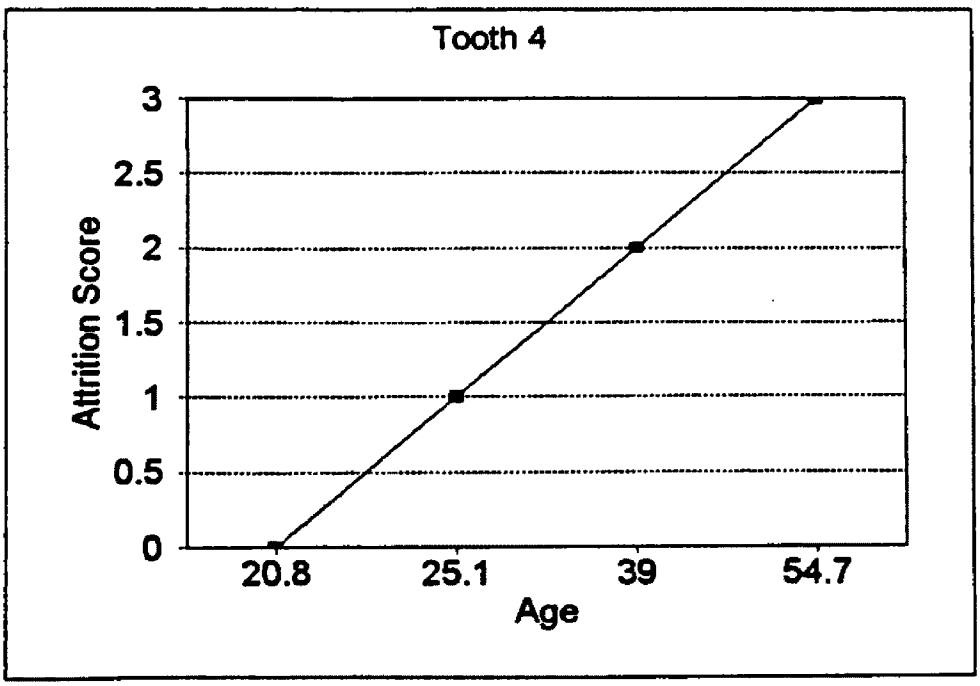
Tooth 4

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	8	20.8	4.3	18-25
1	7	25.1	5.5	20-31
2	1	39	0	0
3	3	54.7	10.8	44-65
4	0	0	0	0

Regression Output:

Constant	-0.8839
Std Err of Y Est	0.73982
R Squared	0.60513
No. of Observations	20
Degrees of Freedom	18

X Coefficient(s)	0.06786
Std Err of Coef.	0.01292



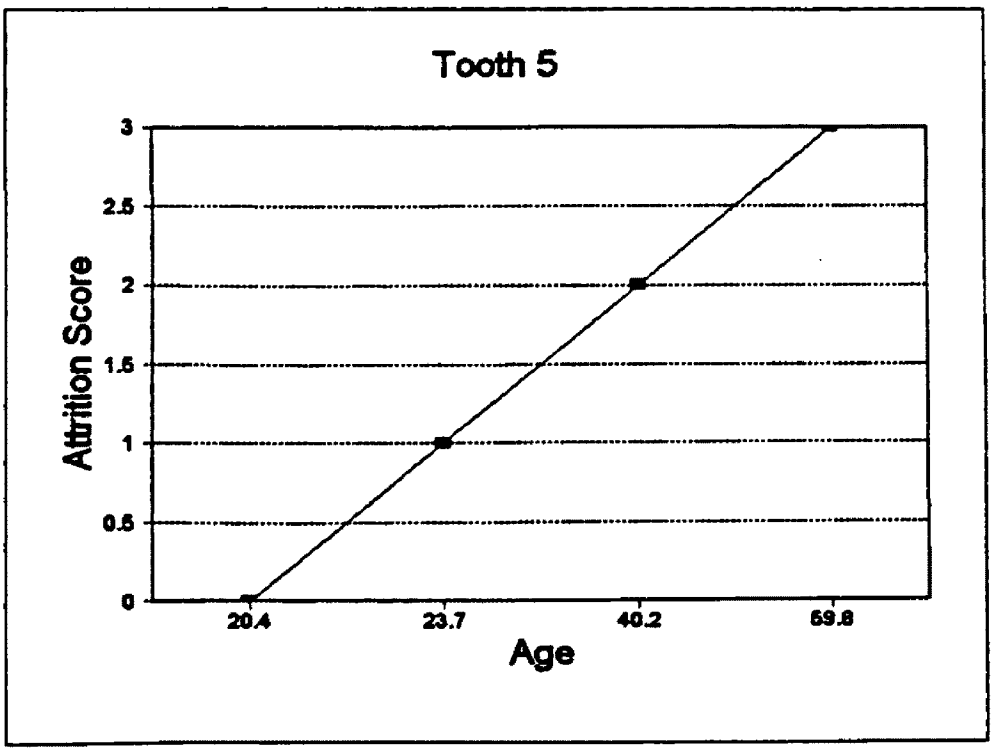
Tooth 5

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	20.4	4	18-24
1	3	23.7	2.5	21-26
2	5	40.2	12.9	27-53
3	4	59.8	13.5	46-73
4	0	0	0	0

Regression Output:

Constant	-0.76096
Std Err of Y Est	0.64304
R Squared	0.73129
No. of Observations	21
Degrees of Freedom	19

X Coefficient(s)	0.05896
Std Err of Coef.	0.0082

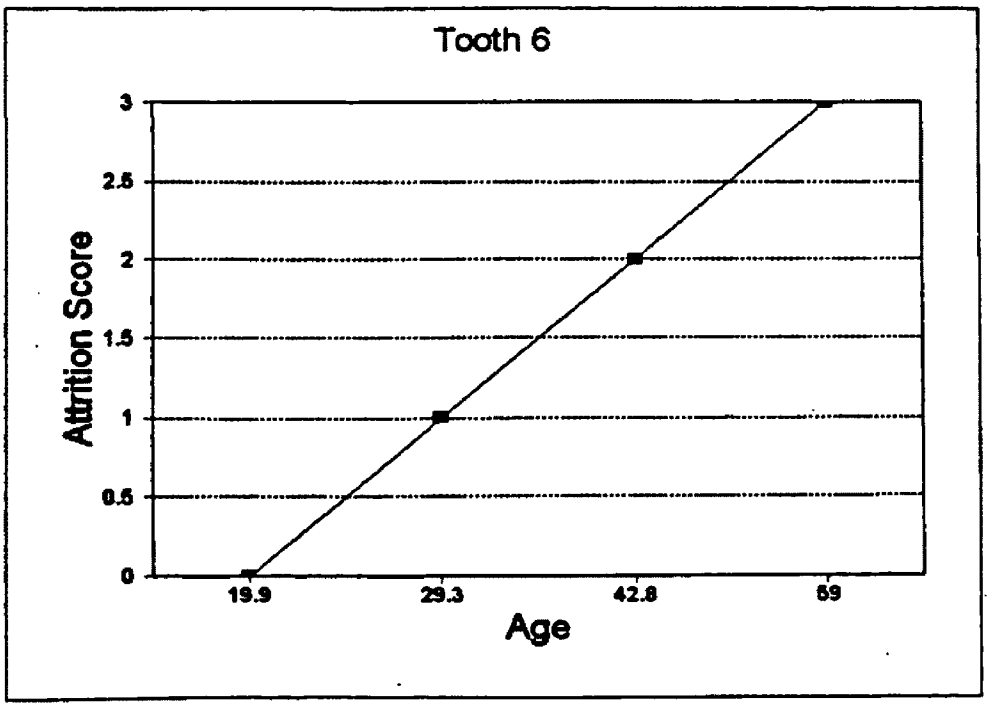


Tooth 6

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	19.9	2.4	18-22
1	4	29.3	6.2	23-36
2	5	42.8	16.5	26-59
3	4	59	15.7	43-75
4	0	0	0	0

Regression Output:

Constant	-0.68049
Std Err of Y Est	0.66623
R Squared	0.69674
No. of Observations	22
Degrees of Freedom	20
X Coefficient(s)	0.05492
Std Err of Coef.	0.0081



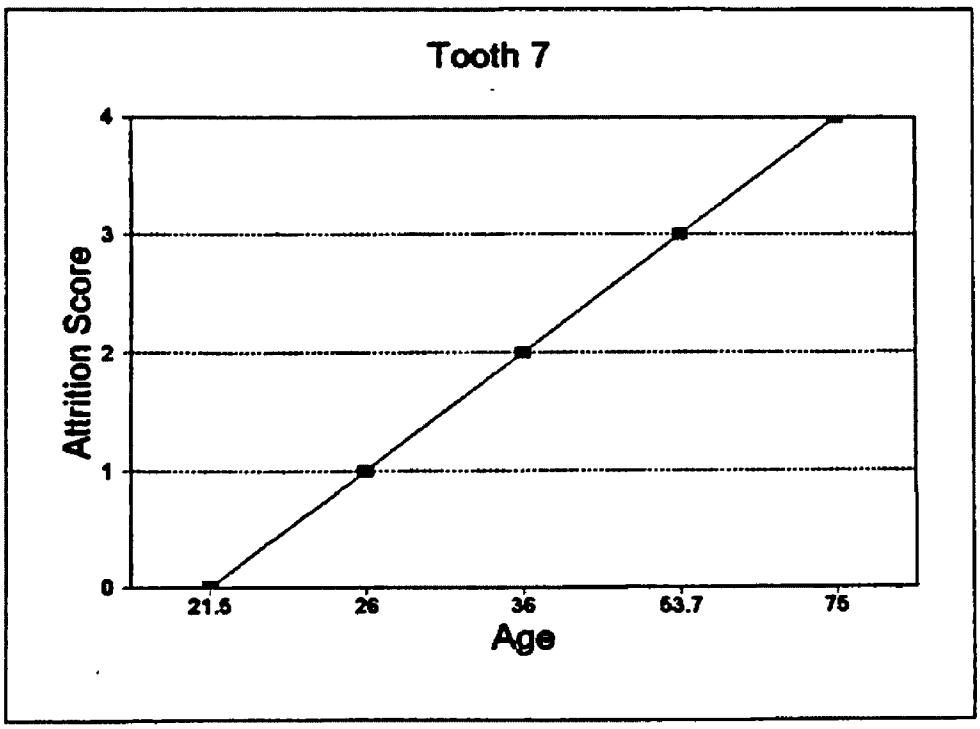
Tooth 7

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	8	21.5	4.6	18-26
1	3	26	5.2	21-31
2	4	36	10.2	26-46
3	3	53.7	14	40-68
4	1	75	0	0

Regression Output:

Constant	-0.9906
Std Err of Y Est	0.67197
R Squared	0.75772
No. of Observations	19
Degrees of Freedom	17

X Coefficient(s)	0.06797
Std Err of Coef.	0.00932



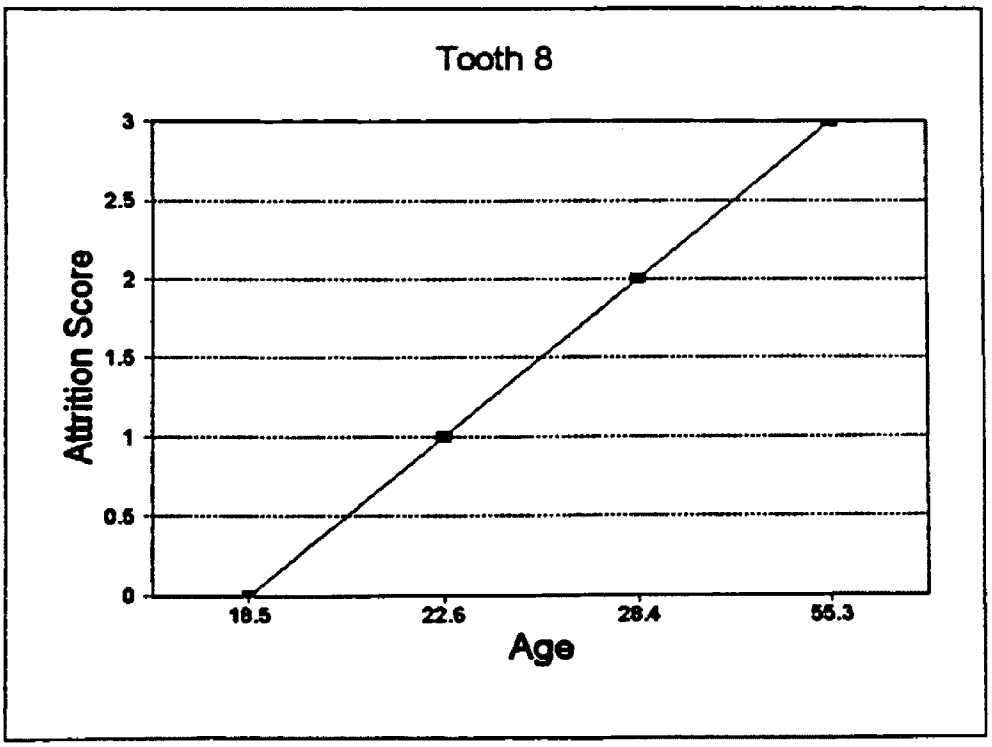
Tooth 8

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	2	18.5	0.7	18-19
1	5	22.6	6.4	18-29
2	7	28.4	10.1	18-39
3	4	55.3	21.1	34-76
4	0	0	0	0

Regression Output:

Constant	0.54508
Std Err of Y Est	0.72722
R Squared	0.45798
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s)	0.03717
Std Err of Coef.	0.01011

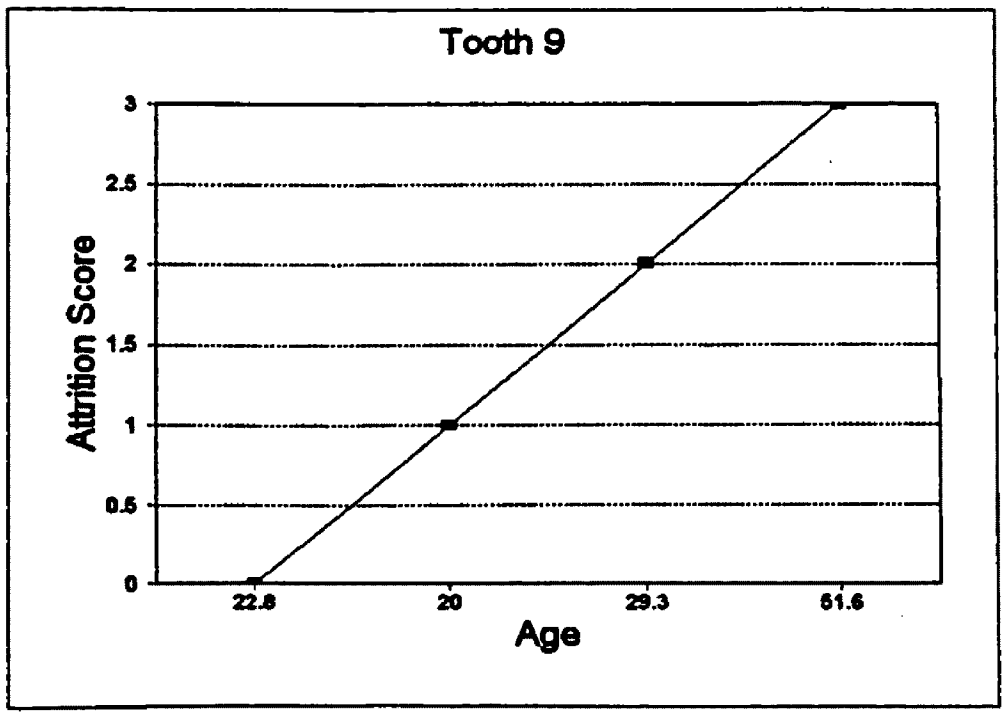


Tooth 9

Attrition score	Number of observations	Average age	Standard deviation	Age Range
0	6	22.8	5	18-28
1	5	20	0.7	19-21
2	4	29.3	4.5	25-34
3	7	51.6	14.8	37-66
4	0	0	0	0

Regression Output:

Constant	
Std Err of Y Est	-0.32281
R Squared	0.82217
No. of Observations	0.5702
Degrees of Freedom	22
	20
X Coefficient(s)	0.05749
Std Err of Coef.	0.01116

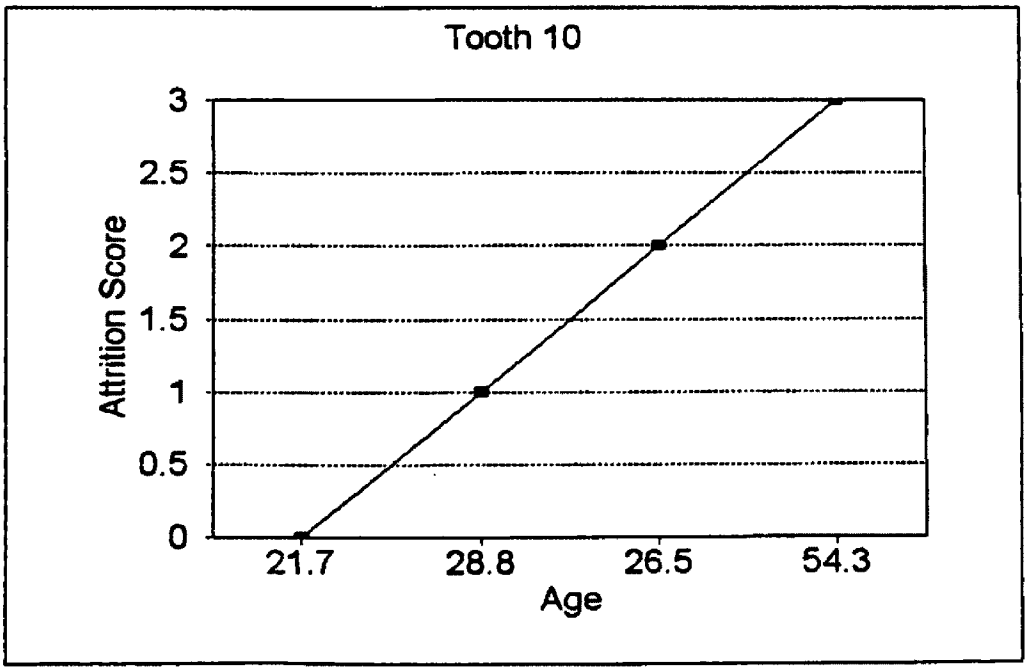


Tooth 10

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	7	21.7	4.9	18-27
1	6	28.8	7.6	21-36
2	2	26.5	3.5	23-30
3	7	54.3	13.1	41-67
4	0	0	0	

Regression Output:

Constant	-0.71821
Std Err of Y Est	0.76329
R Squared	0.65027
No. of Observations	22
Degrees of Freedom	20
X Coefficient(s)	0.06174
Std Err of Coef.	0.01012

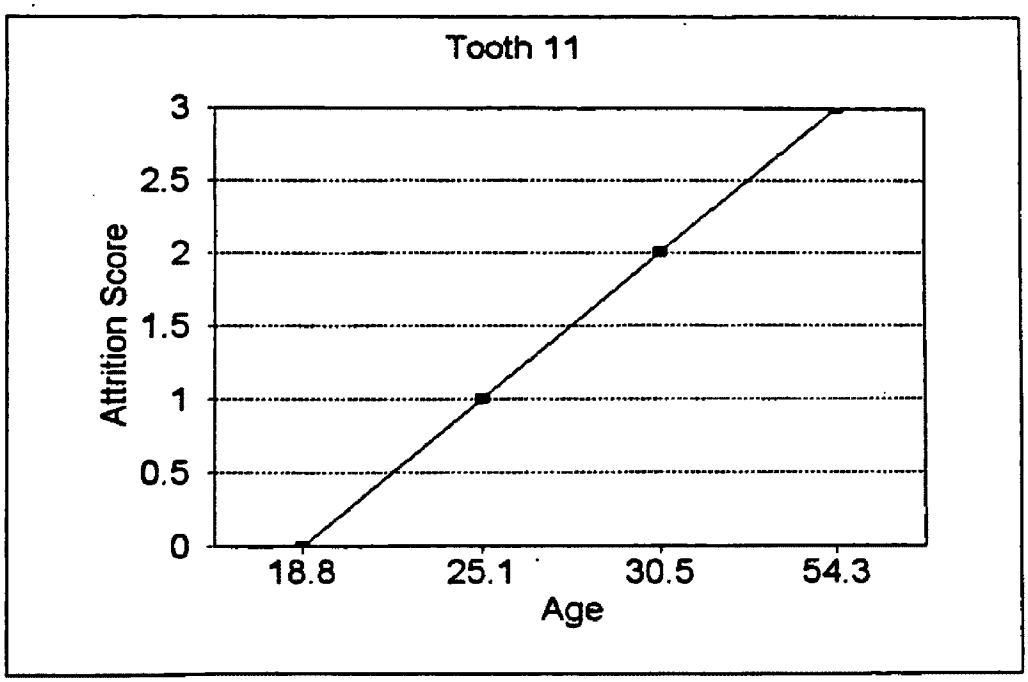


Tooth 11

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	5	18.8	0.8	18-21
1	9	25.1	5.8	19-31
2	4	30.5	5.1	25-36
3	7	54.3	13.1	41-67
4	0	0	0	0

Regression Output:

Constant	-0.40999
Std Err of Y Est	0.62818
R Squared	0.69987
No. of Observations	25
Degrees of Freedom	23
X Coefficient(s)	0.0587
Std Err of Coef.	0.00801



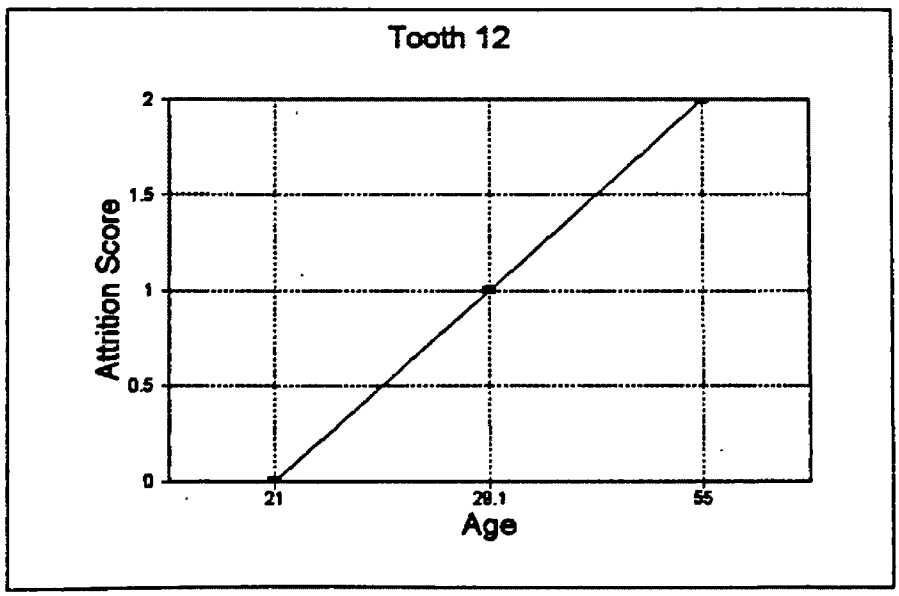
Tooth 12

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	10	21	4.19	18-25
1	7	29.1	6.5	23-36
2	1	55	0	0
3	0	0	0	0
4	0	0	0	0

Regression Output:

Constant	-0.8169
Std Err of Y Est	0.39385
R Squared	0.61817
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s)	0.05054
Std Err of Coef.	0.00993



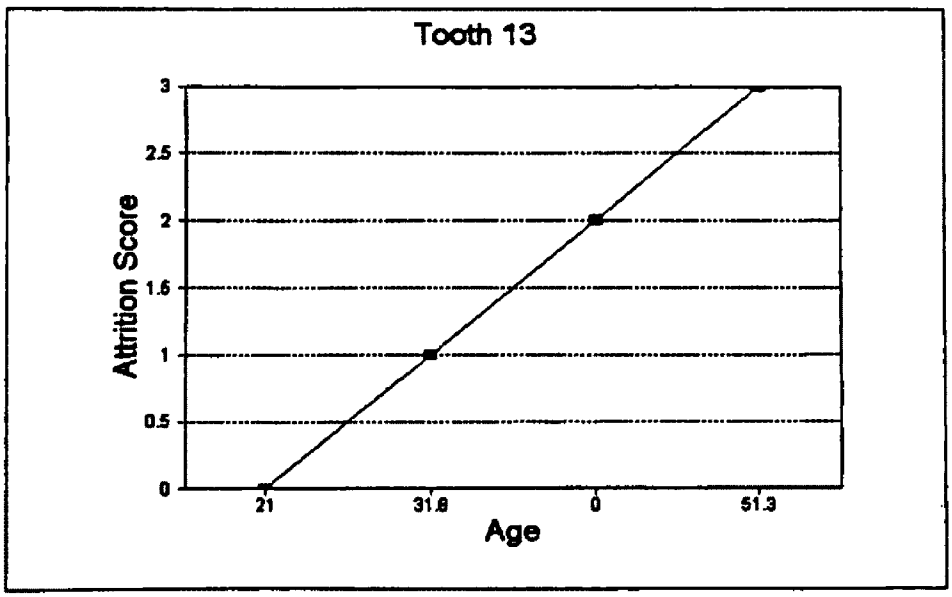
Tooth 13

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	11	21	3.98	18-25
1	4	31.8	3.2	29-35
2	0	0	0	0
3	3	51.3	5.1	46-56
4	0	0	0	0

Regression Output:

Constant	-1.85937
Std Err of Y Est	0.3581
R Squared	0.90506
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s)	0.09111
Std Err of Coef.	0.00738



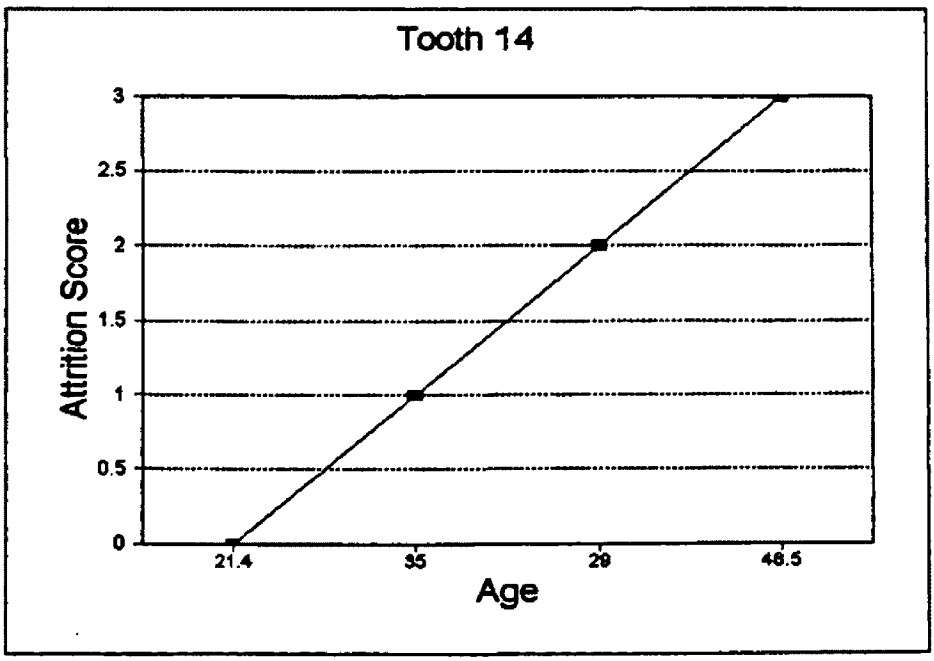
Tooth 14

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	11	21.4	3.95	18-25
1	1	35	0	0
2	1	29	0	0
3	2	48.5	2.1	46-51
4	0	0	0	0

Regression Output:

Constant	-1.98077
Std Err of Y Est	0.50295
R Squared	0.81316
No. of Observations	15
Degrees of Freedom	13

X Coefficient(s)	0.09776
Std Err of Coef.	0.013



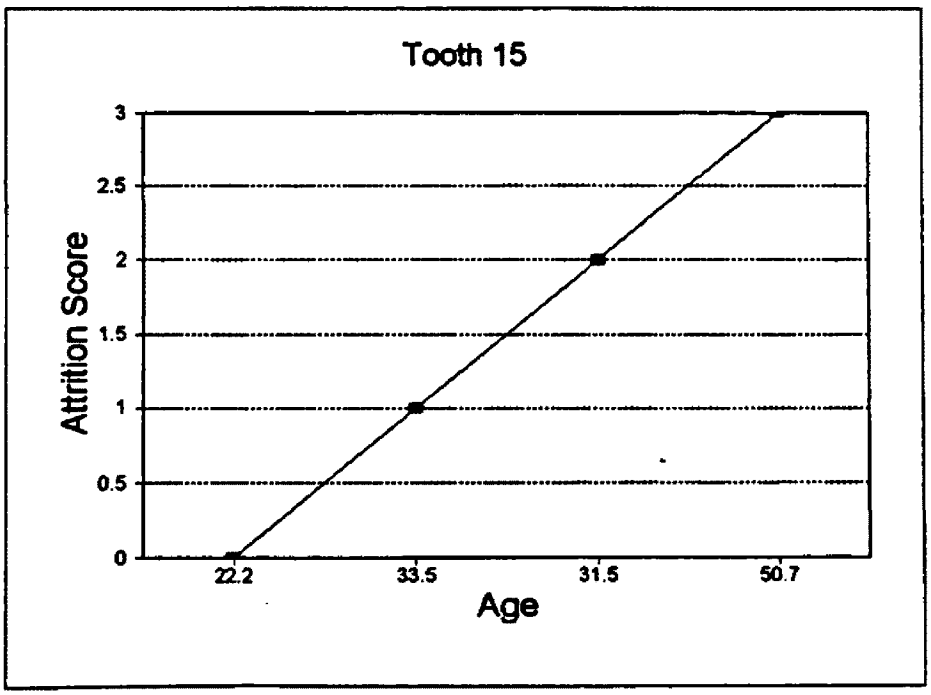
Tooth 15

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	6	22.2	4.6	18-27
1	4	33.5	6.6	27-40
2	2	31.5	3.5	28-35
3	3	50.7	4	47-55
4	0	0	0	0

Regression Output:

Constant	-1.71367	
Std Err of Y Est	0.60096	
R Squared	0.76208	0.87297
No. of Observations	15	
Degrees of Freedom	13	

X Coefficient(s)	0.0886
Std Err of Coef.	0.01373



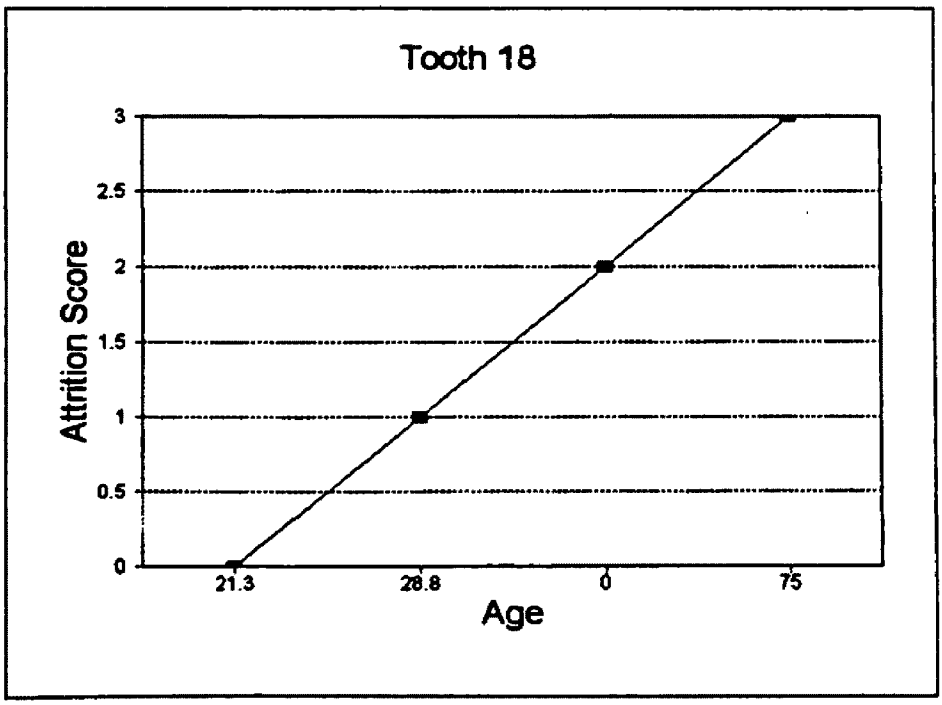
Tooth 18

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	21.3	4.3	18-26
1	5	28.8	6.7	22-35
2	0	0	0	0
3	1	75	0	0
4	0	0	0	0

Regression Output:

Constant	-0.862
Std Err of Y Est	0.40238
R Squared	0.78375
No. of Observations	15
Degrees of Freedom	13

X Coefficient(s)	0.05092
Std Err of Coef.	0.00742

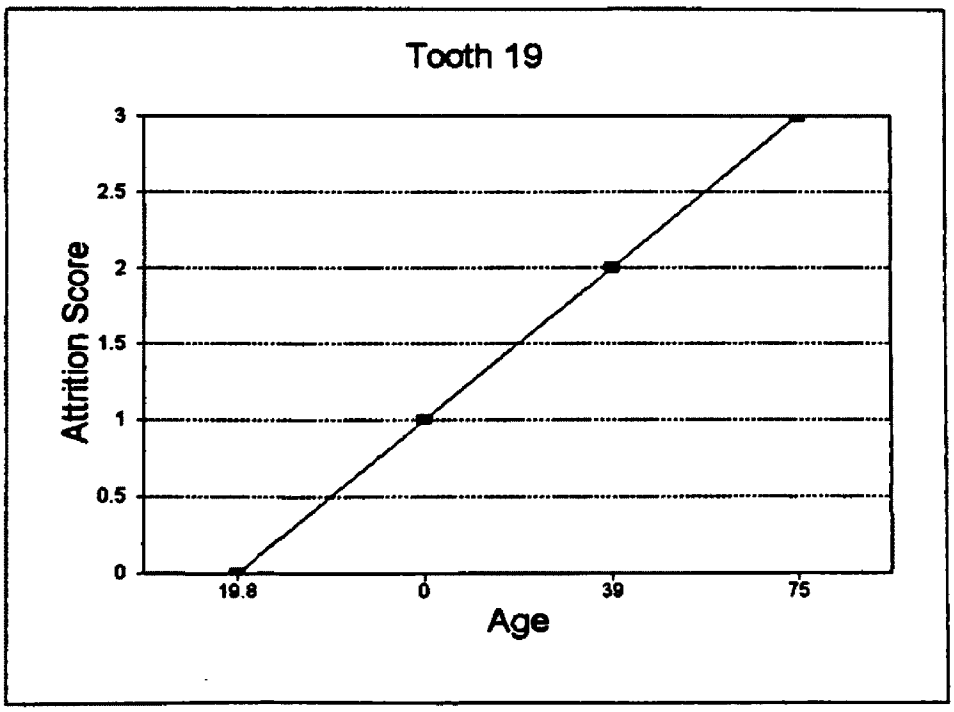


Tooth 19

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	8	19.8	1.7	18-22
1	0	0	0	0
2	1	39	0	0
3	1	75	0	0
4	0	0	0	0

Regression Output:

Constant	-1.07307
Std Err of Y Est	0.32439
R Squared	0.91983
No. of Observations	10
Degrees of Freedom	8
X Coefficient(s)	0.05783
Std Err of Coef.	0.00604

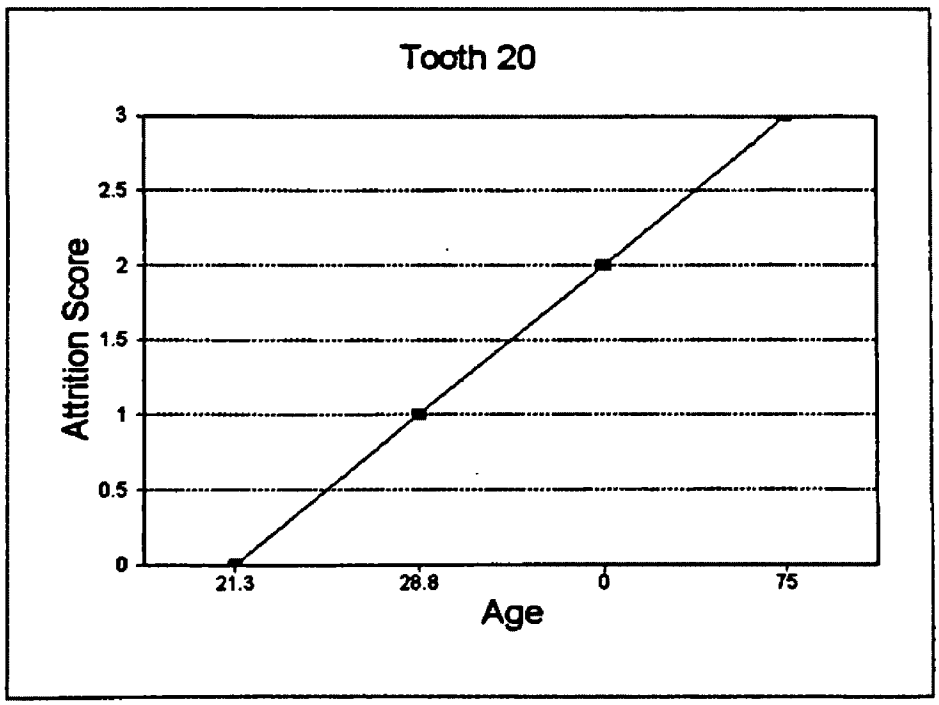


Tooth 20

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	21.3	4.3	18-26
1	5	28.8	6.8	22-35
2	0	0	0	0
3	1	75	0	0
4	0	0	0	0

Regression Output:

Constant	-0.862
Std Err of Y Est	0.40238
R Squared	0.78375
No. of Observations	15
Degrees of Freedom	13
X Coefficient(s)	0.05092
Std Err of Coef.	0.00742

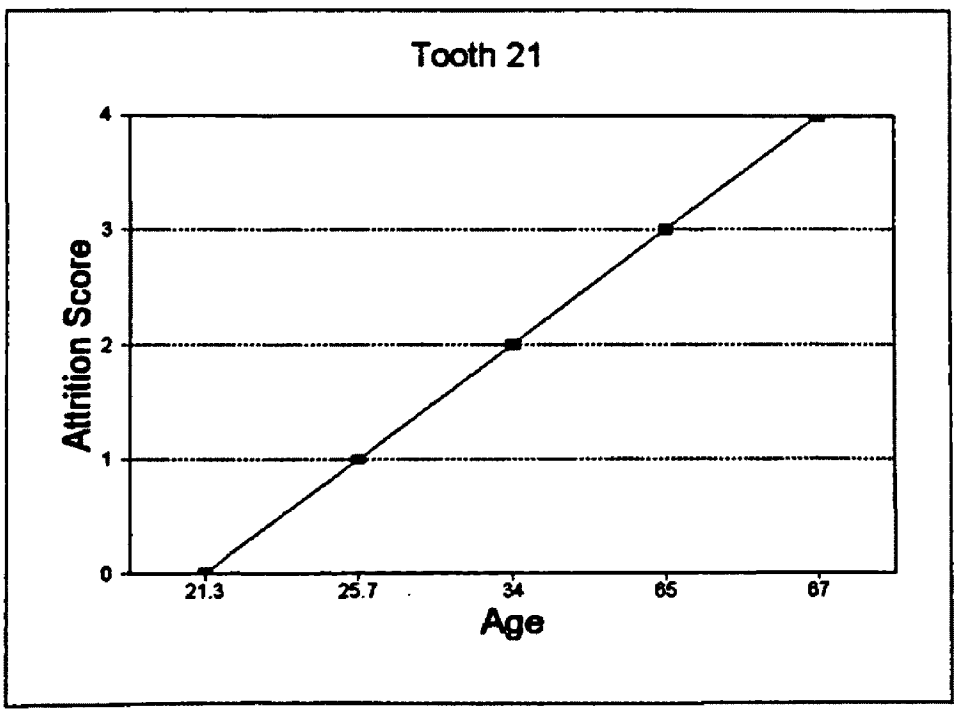


Tooth 21

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	21.3	4.3	18-26
1	3	25.7	9	18-35
2	2	34	7.1	27-41
3	2	65	14.1	51-79
4	1	67	0	0

Regression Output:

Constant	-1.07234
Std Err of Y Est	0.62005
R Squared	0.79404
No. of Observations	17
Degrees of Freedom	15
X Coefficient(s)	0.06597
Std Err of Coef.	0.00868

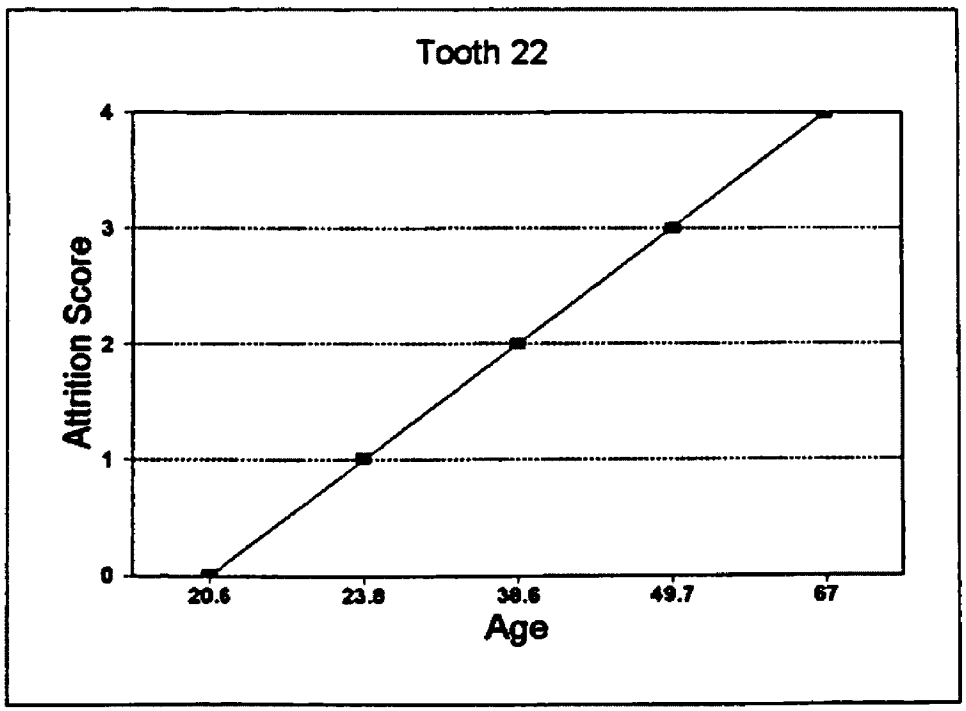


Tooth 22

Attrition score	Number of observations	Average age	Standard Deviation	Age range
0	5	20.6	3.1	18-24
1	4	23.8	5	19-29
2	5	38.6	13.2	25-52
3	3	49.7	22	28-72
4	1	67	0	0

Regression Output:

Constant	-0.41725
Std Err of Y Est	0.8011
R Squared	0.61252
No. of Observations	18
Degrees of Freedom	16
X Coefficient(s)	0.05685
Std Err of Coef.	0.0113

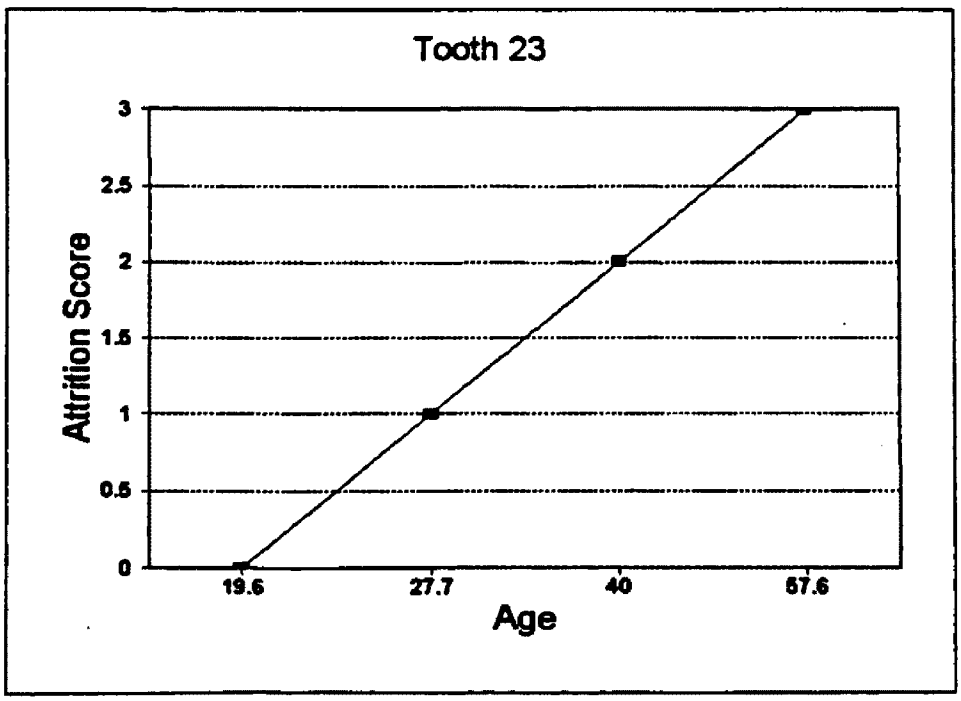


Tooth 23

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	7	19.6	1	19-21
1	4	27.7	4.6	23-32
2	3	40	13.5	27-54
3	5	57.6	14.2	43-72
4	0	0	0	0

Regression Output:

Constant	-0.73067
Std Err of Y Est	0.62956
R Squared	0.76026
No. of Observations	19
Degrees of Freedom	17
X Coefficient(s)	0.06019
Std Err of Coef.	0.0082



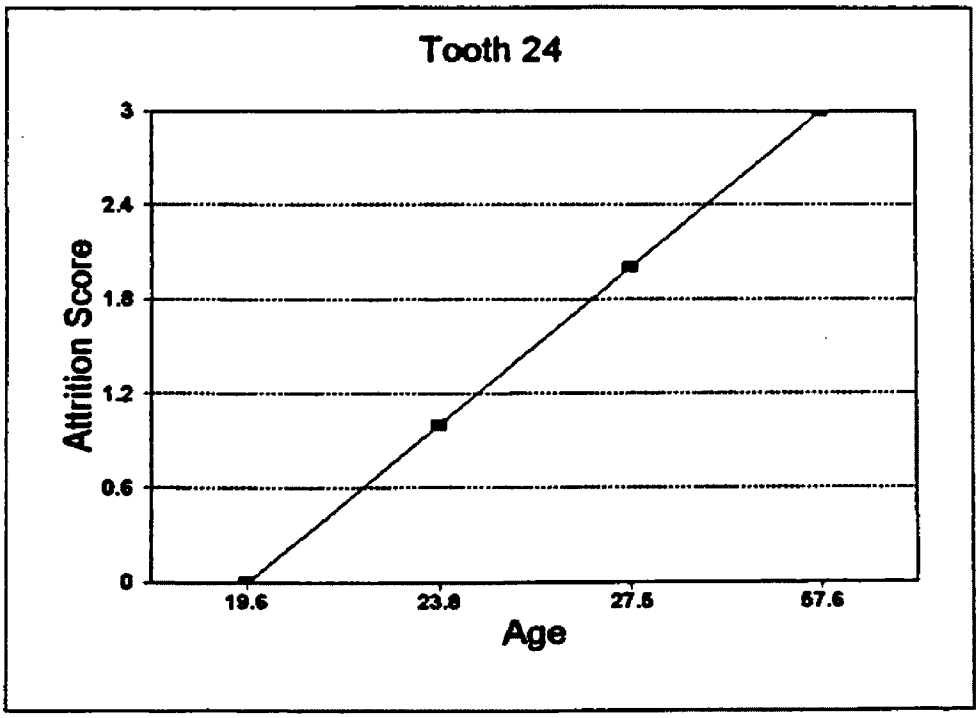
Tooth 24

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	5	19.6	0.5	19-20
1	4	23.8	5.9	18-30
2	4	27.5	6.6	21-34
3	5	57.6	14.2	43-72
4	0	0	0	0

Regression Output:

Constant	-0.26783
Std Err of Y Est	0.73955
R Squared	0.64281
No. of Observations	18
Degrees of Freedom	16

X Coefficient(s)	0.05384
Std Err of Coef.	0.01003



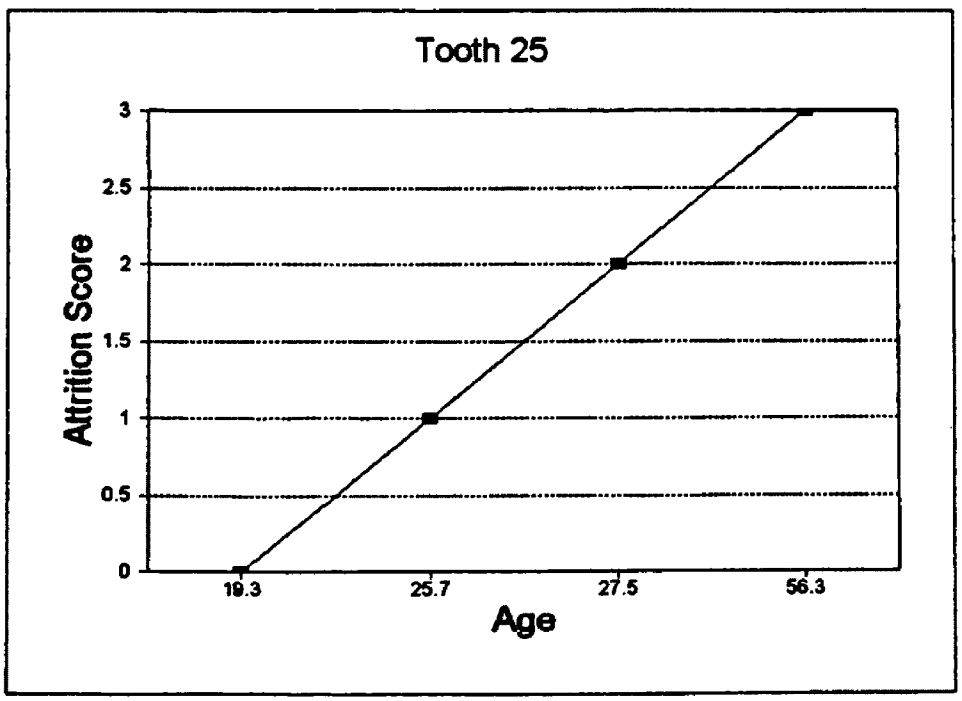
Tooth 25

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	6	19.3	0.8	19-20
1	3	25.7	5.5	20-31
2	4	27.5	6.6	21-32
3	3	56.3	18	38-74
4	0	0		0

Regression Output:

Constant	-0.46363
Std Err of Y Est	0.78235
R Squared	0.59195
No. of Observations	16
Degrees of Freedom	14

X Coefficient(s)	0.05809
Std Err of Coef.	0.01289



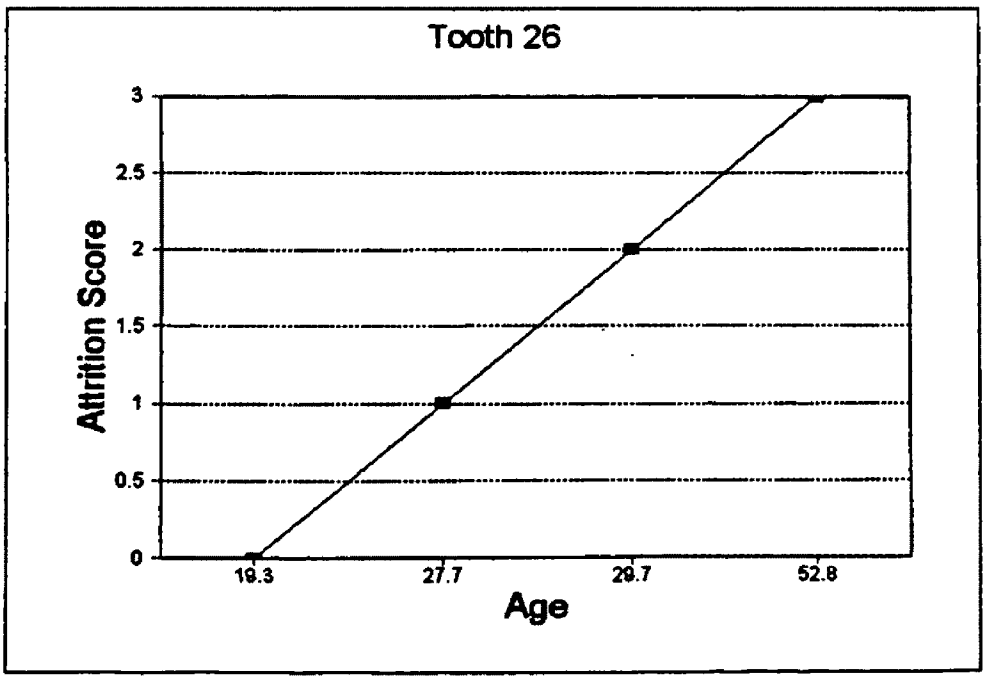
Tooth 26

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	7	19.3	0.8	19-20
1	3	27.7	2.9	24-31
2	3	29.7	6	24-36
3	4	52.8	16.4	36-69
4	0	0	0	0

Regression Output:

Constant	-0.81086
Std Err of Y Est	0.73004
R Squared	0.68097
No. of Observations	17
Degrees of Freedom	15

X Coefficient(s)	0.06715
Std Err of Coef.	0.01187

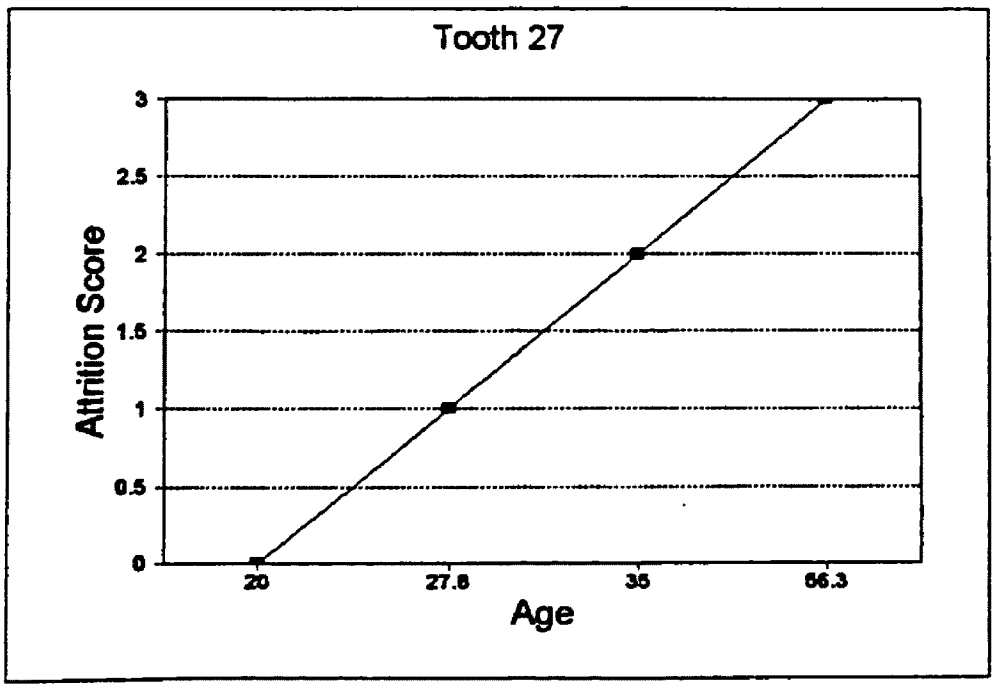


Tooth 27

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	8	20	2.6	18-23
1	4	27.8	7.1	21-35
2	3	35	6.6	28-42
3	3	56.3	18	38-74
4	0	0	0	0

Regression Output:

Constant	-0.90164
Std Err of Y Est	0.64266
R Squared	0.71199
No. of Observations	18
Degrees of Freedom	16
X Coefficient(s)	0.06464
Std Err of Coef.	0.01028



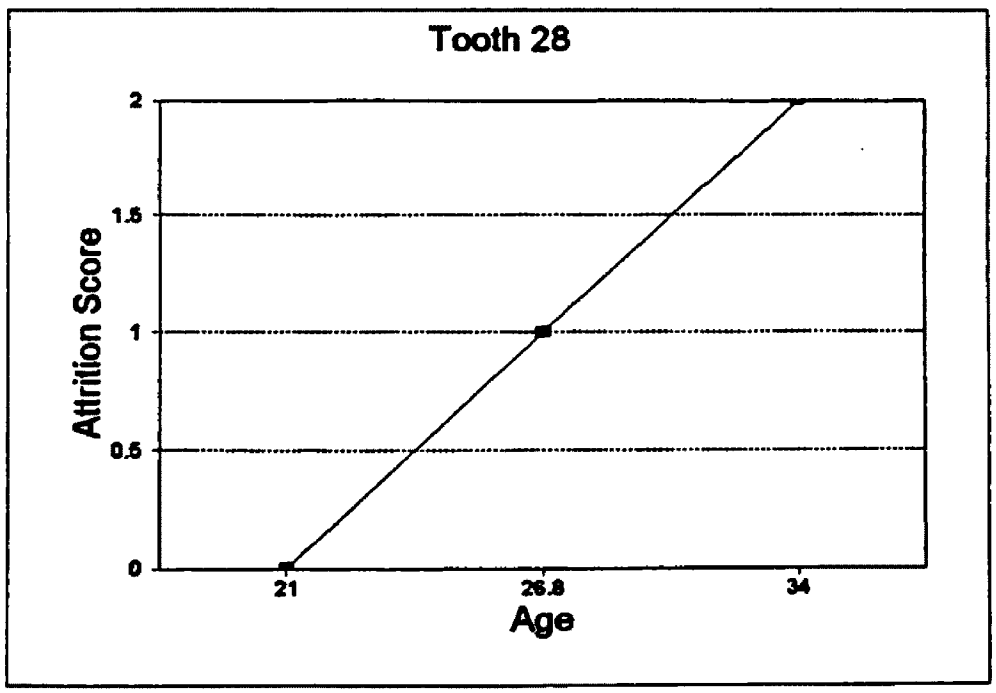
Tooth 28

Attrition score	Number of observations	Average age	standard deviation	Age range
0	7	21	4.5	18-25
1	4	26.8	6.5	20-33
2	3	34	5	29-39
3	0	0	0	0
4	0	0	0	0

Regression Output:

Constant	-1.45952
Std Err of Y Est	0.57799
R Squared	0.54739
No. of Observations	14
Degrees of Freedom	12

X Coefficient(s)	0.08549
Std Err of Coef.	0.02244

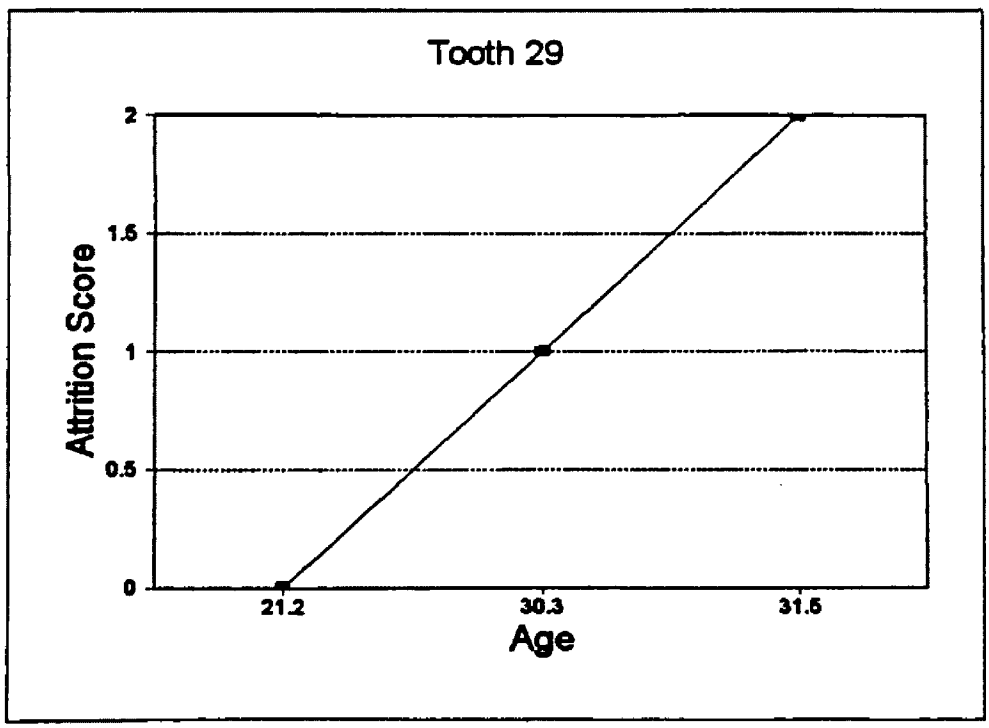


Tooth 29

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	9	21.2	3.9	18-25
1	4	30.3	6.1	24-36
2	2	31.5	3.5	28-35
3	0	0	0	0
4	0	0	0	0

Regression Output:

Constant	-1.52086
Std Err of Y Est	0.54571
R Squared	0.49938
No. of Observations	15
Degrees of Freedom	13
X Coefficient(s)	0.08217
Std Err of Coef.	0.02282

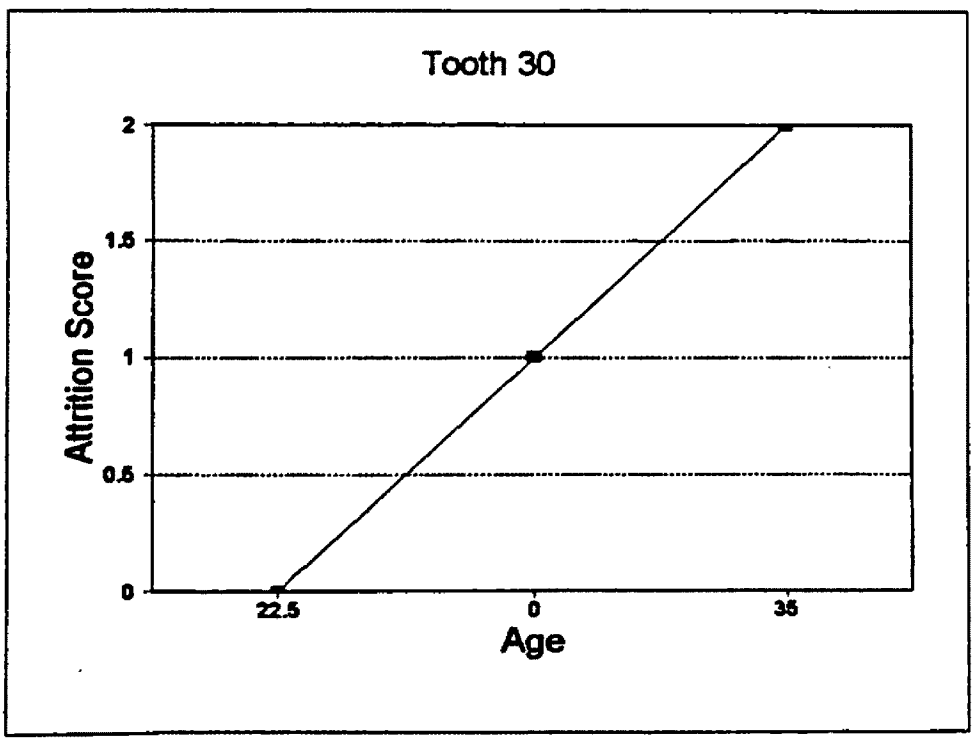


Tooth 30

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	8	22.5	4.1	18-27
1	0	0	0	0
2	1	35	0	0
3	0	0	0	0
4	0	0	0	0

Regression Output:

Constant	-1.84429
Std Err of Y Est	0.48303
R Squared	0.54066
No. of Observations	9
Degrees of Freedom	7
X Coefficient(s)	0.08651
Std Err of Coef.	0.03014



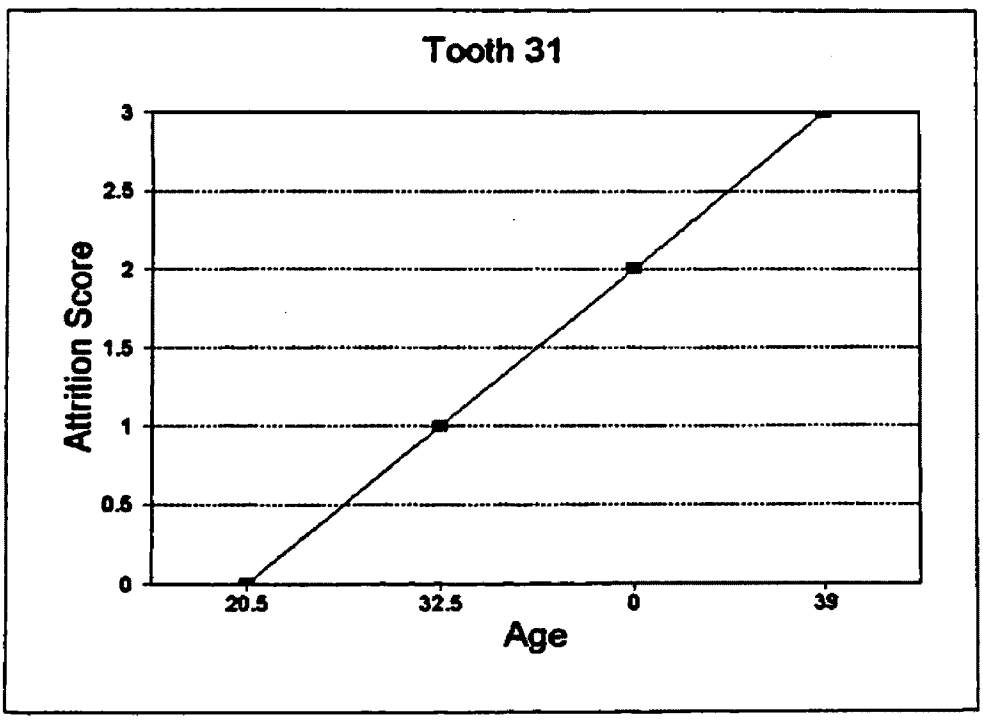
Tooth 31

Attrition score	Number of observations	Average age	Standard deviation	Age range
0	4	20.5	1.7	19-22
1	2	32.5	5	28-38
2	0	0	0	0
3	1	39	0	0
4	0	0	0	0

Regression Output:

Constant	-2.50423
Std Err of Y Est	0.54333
R Squared	0.8013
No. of Observations	7
Degrees of Freedom	5

X Coefficient(s)	0.12113
Std Err of Coef.	0.02697



Appendix IV

Glossary

Bruxism - mandibular and maxillary movement causing grinding of the teeth against other teeth.

Crown - the part of the tooth situated above the gum and covered with enamel.

Dentin - the chief tissue of the tooth that surrounds the pulp cavity.

Enamel - a white hard substance covering the dentin of the tooth crown.

Mandible - a lower jaw.

Masticating - to grind or crush food with the teeth in preparation for swallowing.

Maxilla - an upper jaw.

Occlusal - of or relating to the grinding or biting surface of the tooth.

Occlusal Plane - masticating surface of the teeth.

Pulp Cavity - pulp chamber within the tooth containing the tissue pulp.